BIO-SYSTEMS AS SELF-ORGANIZING QUANTUM SYSTEMS

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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 $H = M^4 \times CP_2$ [L76]. 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 [L33, L43](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 [L77].

- 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 [K122, L52].

- 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 [K27, K56] [L72].

- 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 [L74]. 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 geneneral 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 [L79].

- 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 [L31, L32] 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 [L78]. 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. 22**). 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 light-cones. The notion of energy-momentum becomes length scale dependent since one has a scale hierarchy for causal diamonds. This allows to understand the non-conservation of energy as apparent.

  Equivalence Principle 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 space-time of TGD by lumping together the space-time sheets to a regionof Minkowski space and endowing it with an effective metric given as a sum of Minkowski metric and deviations of the metrices of space-time sheets from Minkowski metric. Similar description relates classical gauge potentials identified as components of induced spinor connection to Yang-Mills gauge potentials in GRT space-time. Various topological inhomogenities below resolution scale identified as particles are described using energy momentum tensor and gauge currents.

  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 [L69], 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 [A12]. I have proposed [K46, K30, K119, K88, L77] 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 [K122, L52] 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 [L75]. 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 [L66, L67] 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 infinite-dimensional 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 [L79].

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 3-surfaces. 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 [L73]. 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.

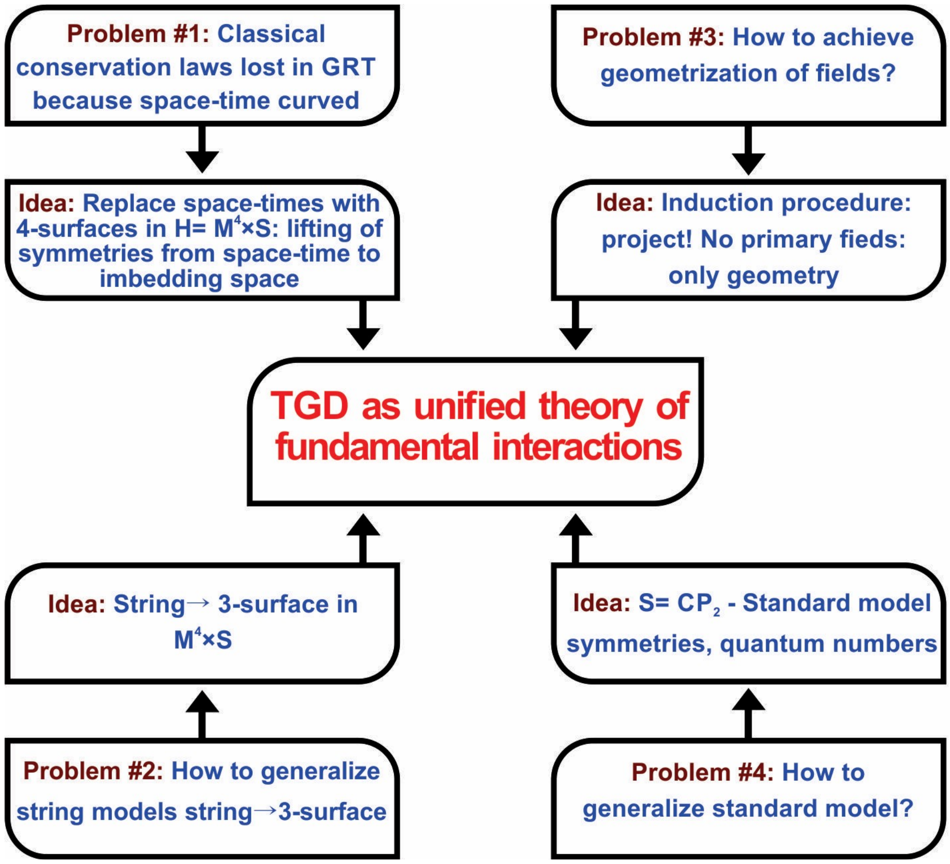

Figure 1: The problems leading to TGD as their solution.

- 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.

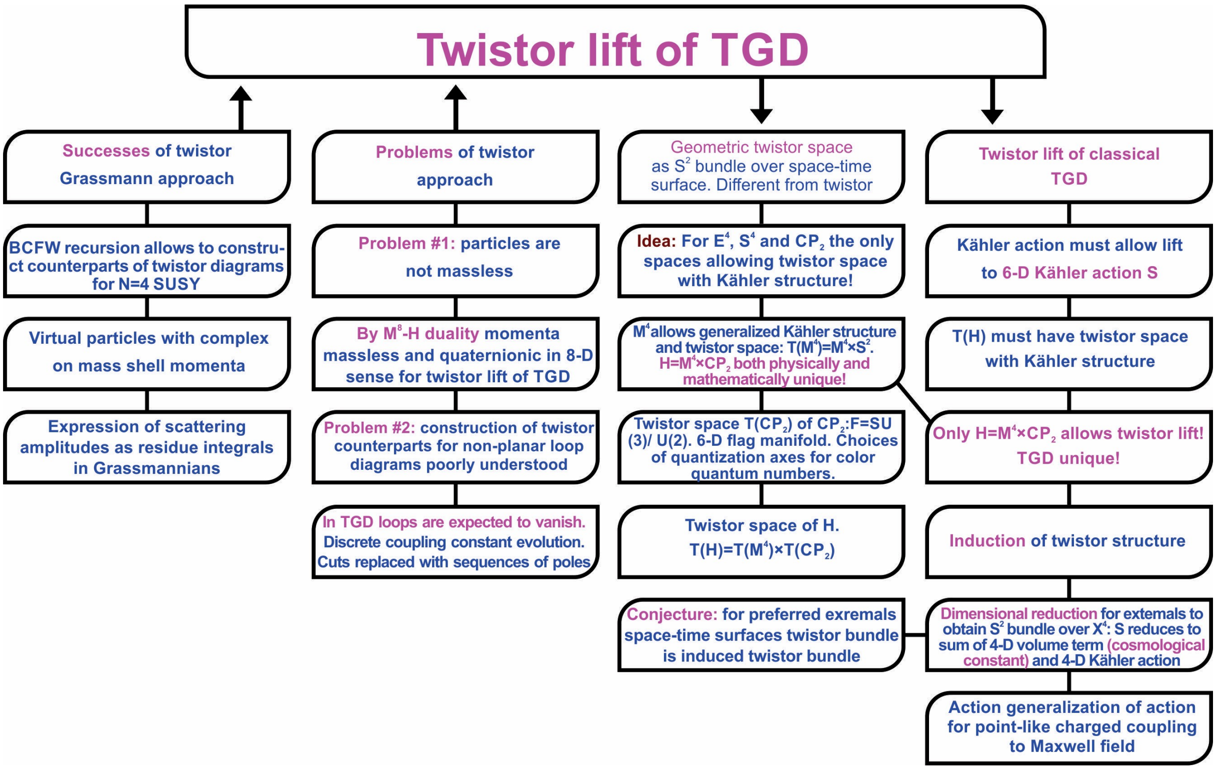

Figure 2: Twistor lift

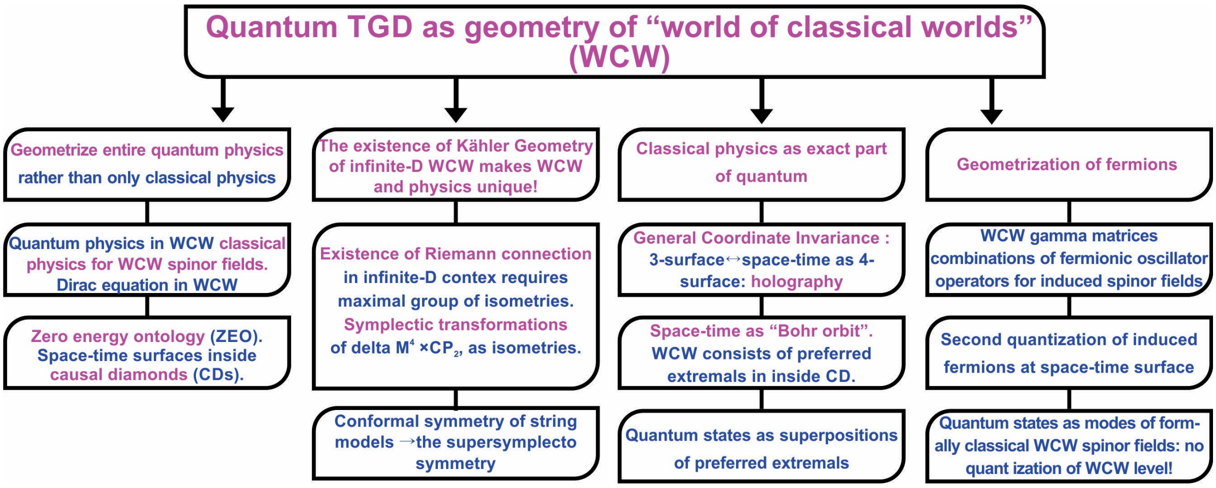

Figure 3: Geometrization of quantum physics in terms of WCW

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

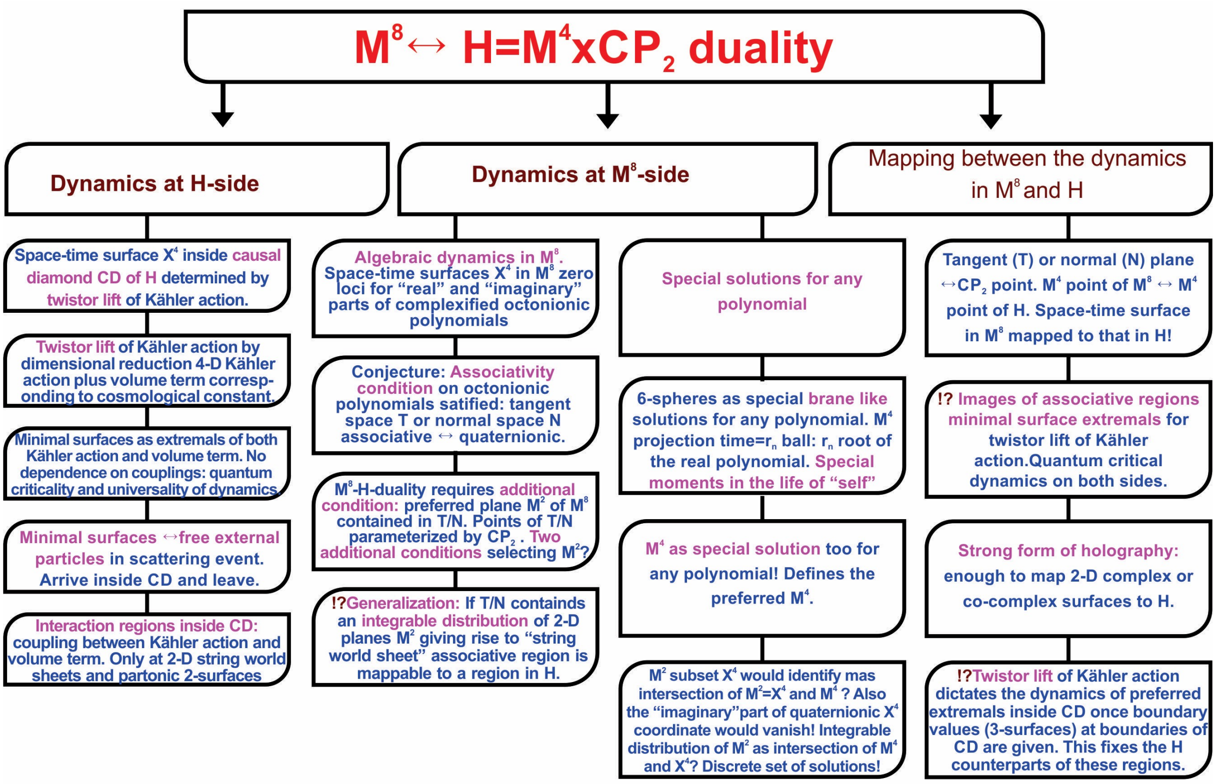

Figure 4: $M^8 - H$ duality

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

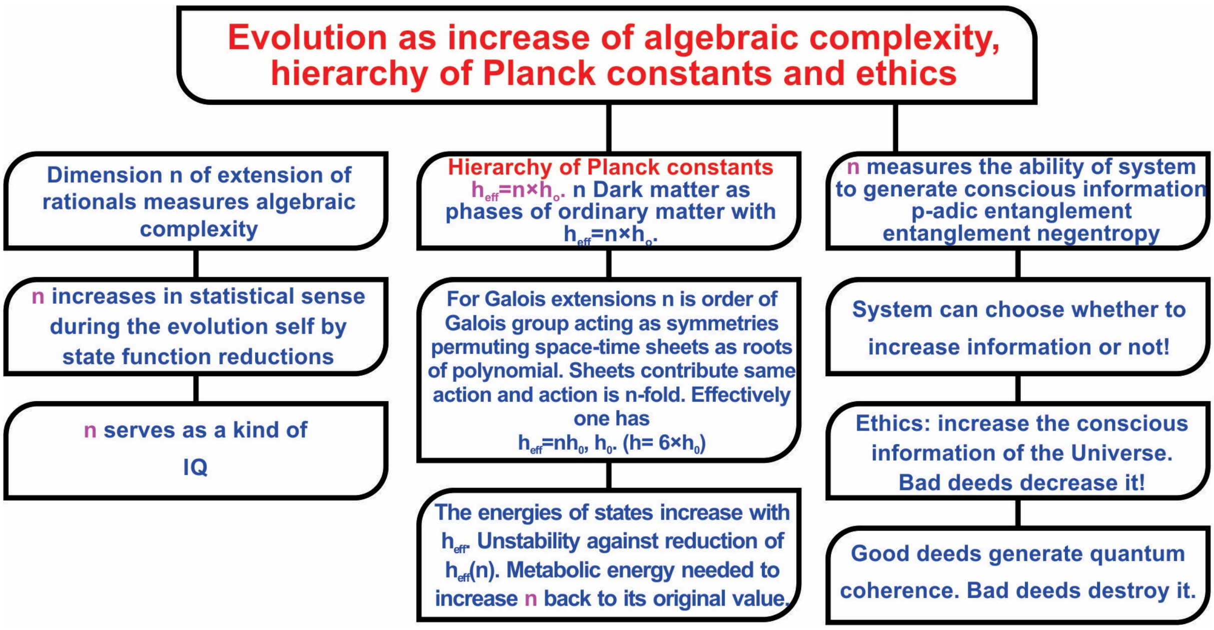

Figure 5: Number theoretic view of evolution

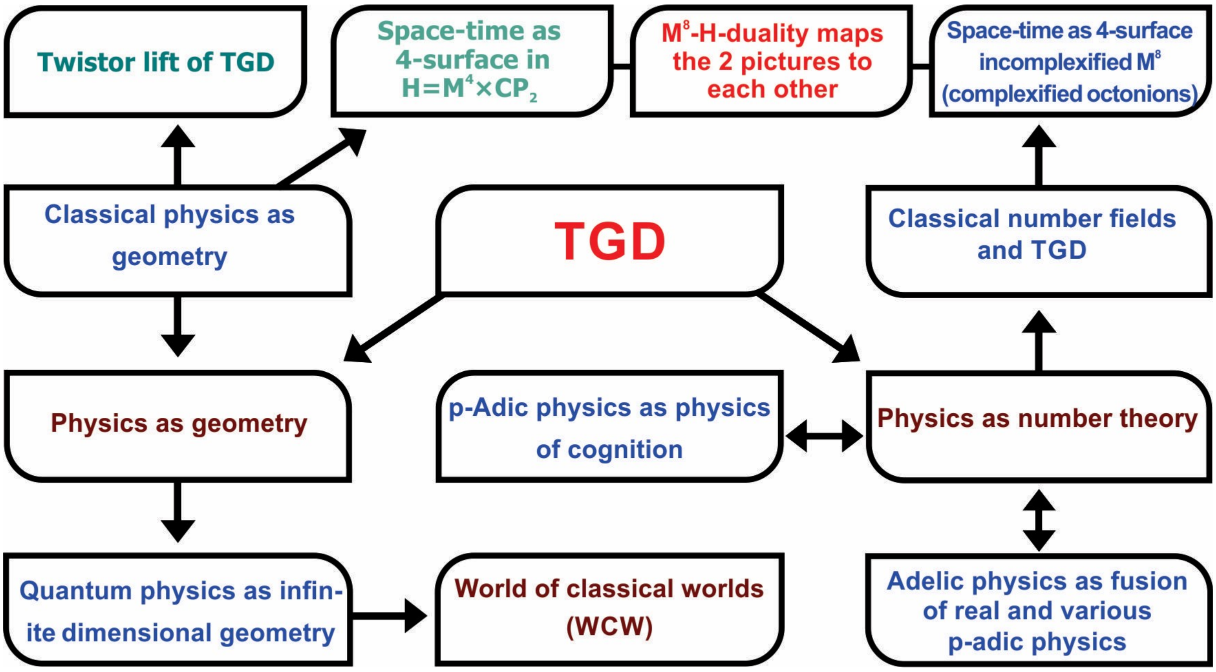

Figure 6: TGD is based on two complementary visions: physics as geometry and physics as number theory.

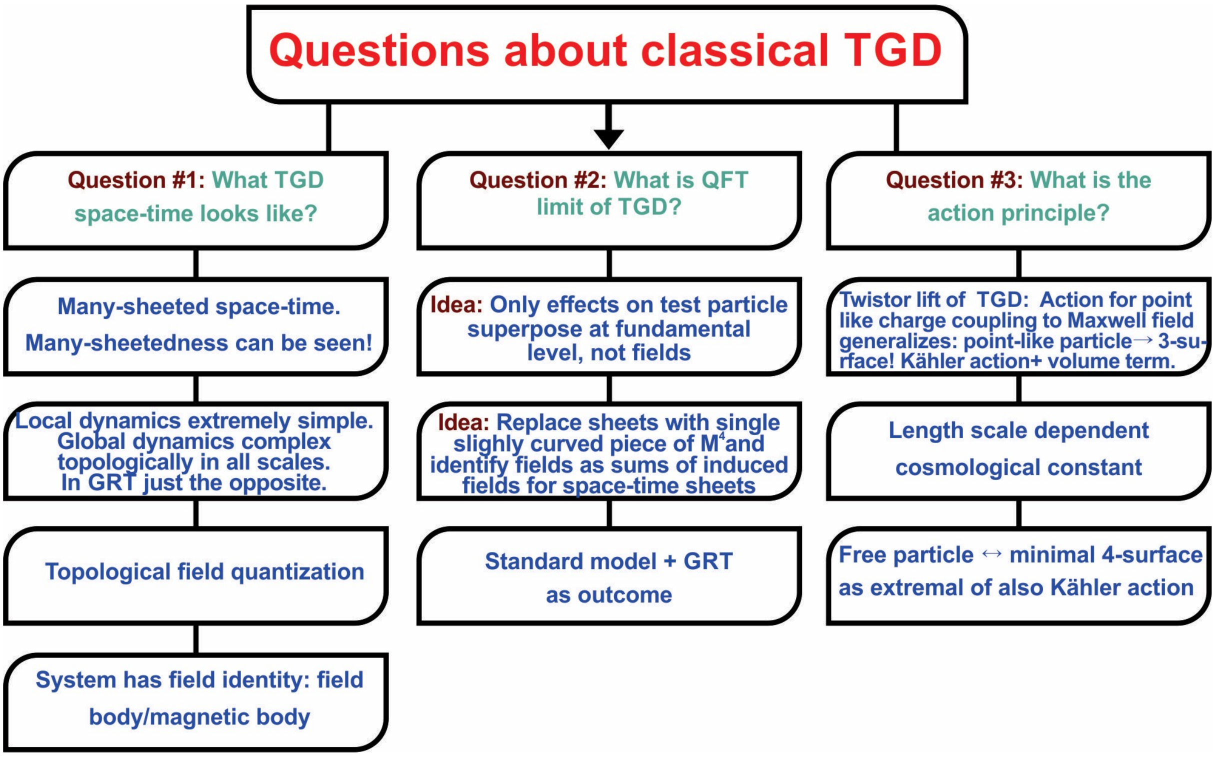

Figure 7: Questions about classical TGD.

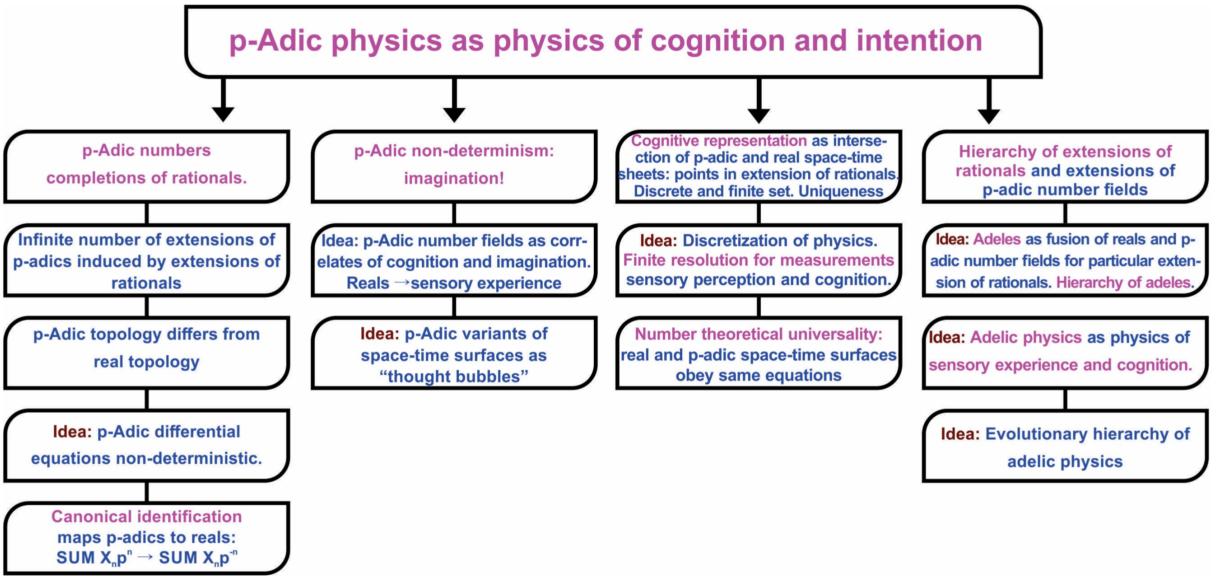

Figure 8: p-Adic physics as physics of cognition and imagination.

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 tranfer 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.

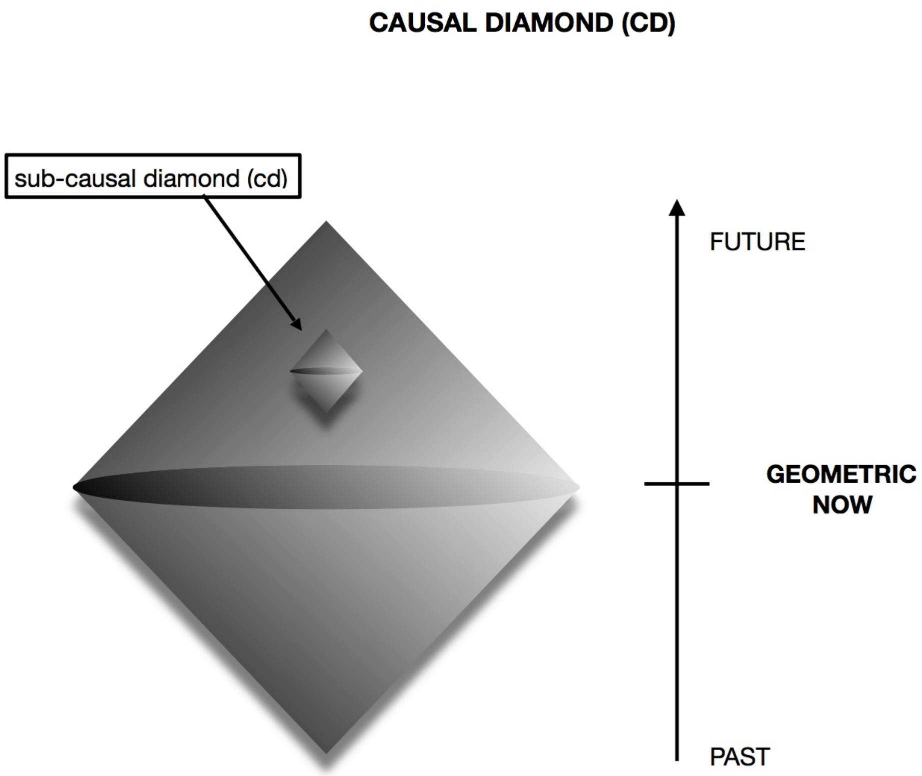

Figure 9: Causal diamond

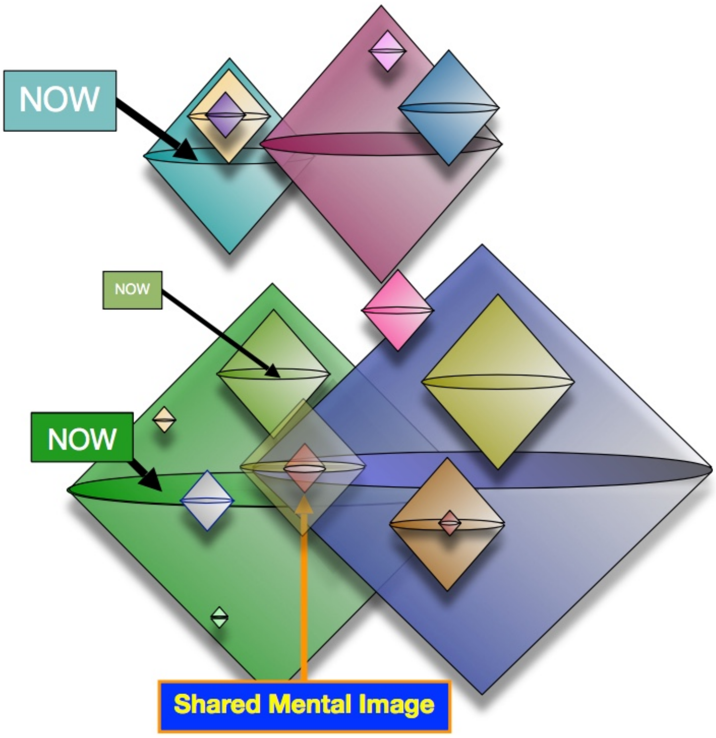

Figure 10: CDs define a fractal “conscious atlas”

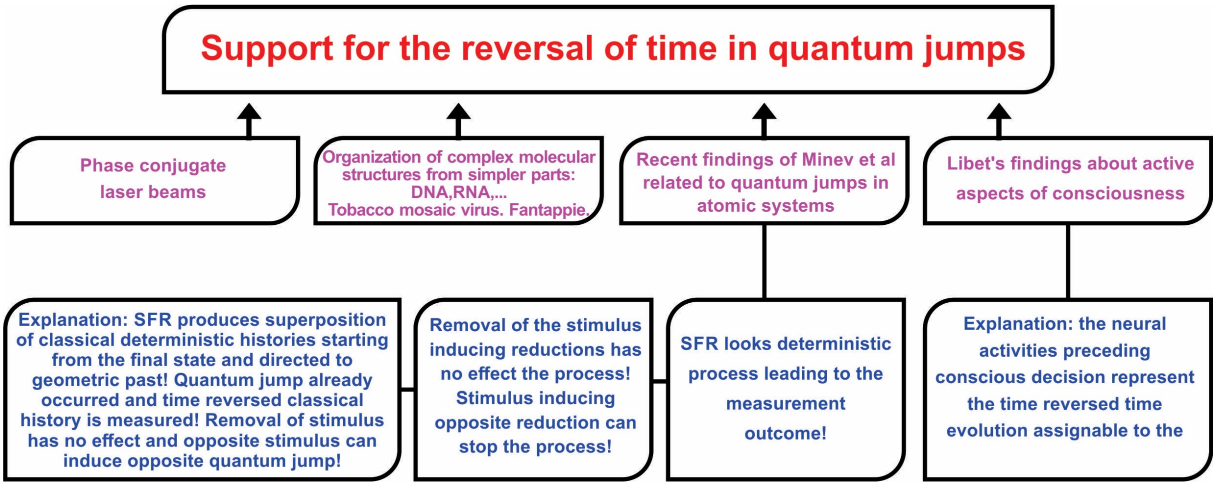

Figure 11: Time reversal occurs in BSFR

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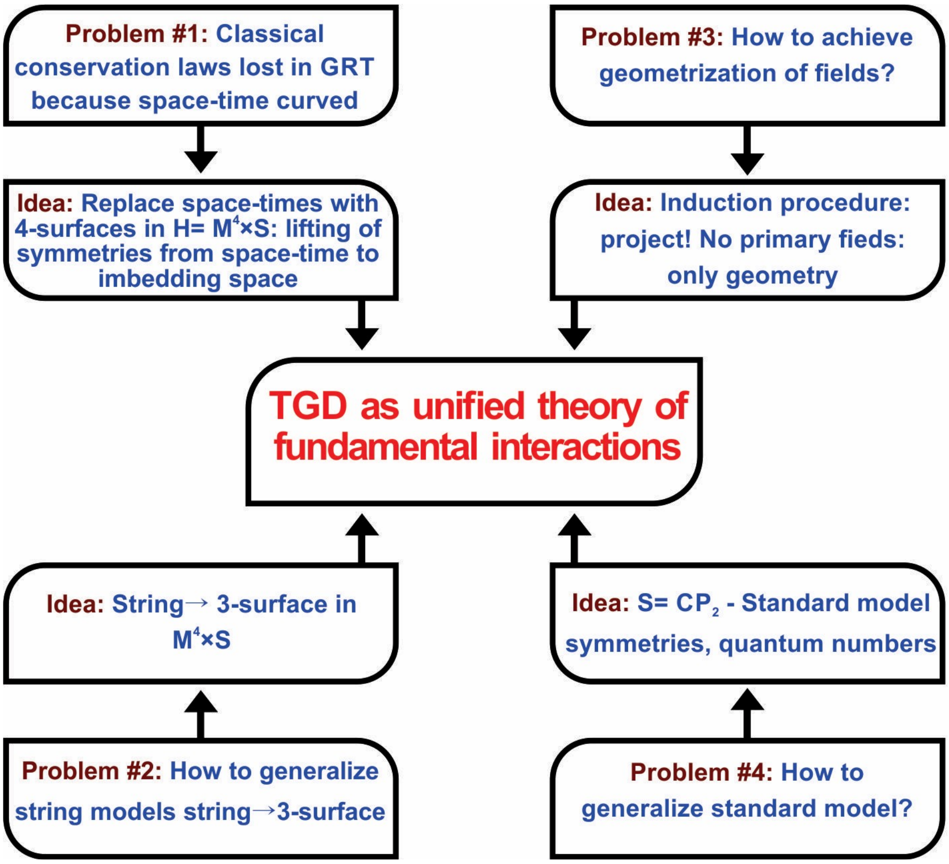
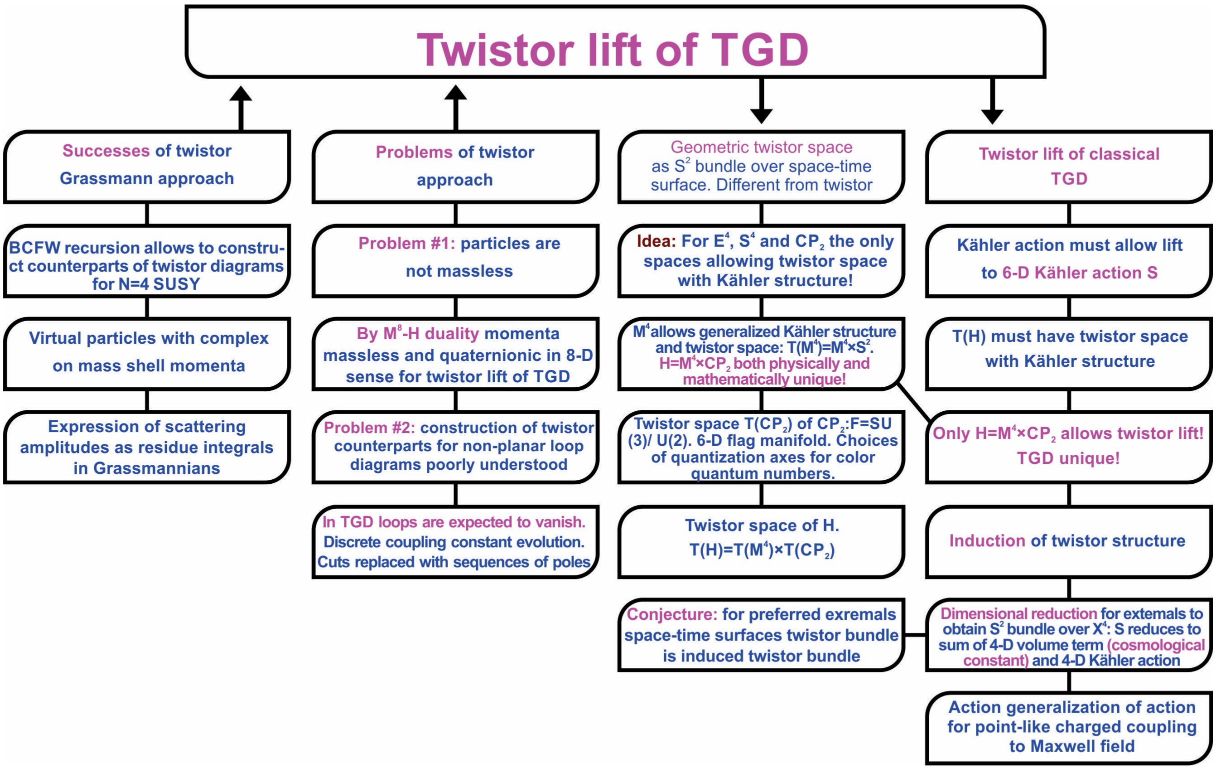


Figure 12: The problems leading to TGD as their solution.

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



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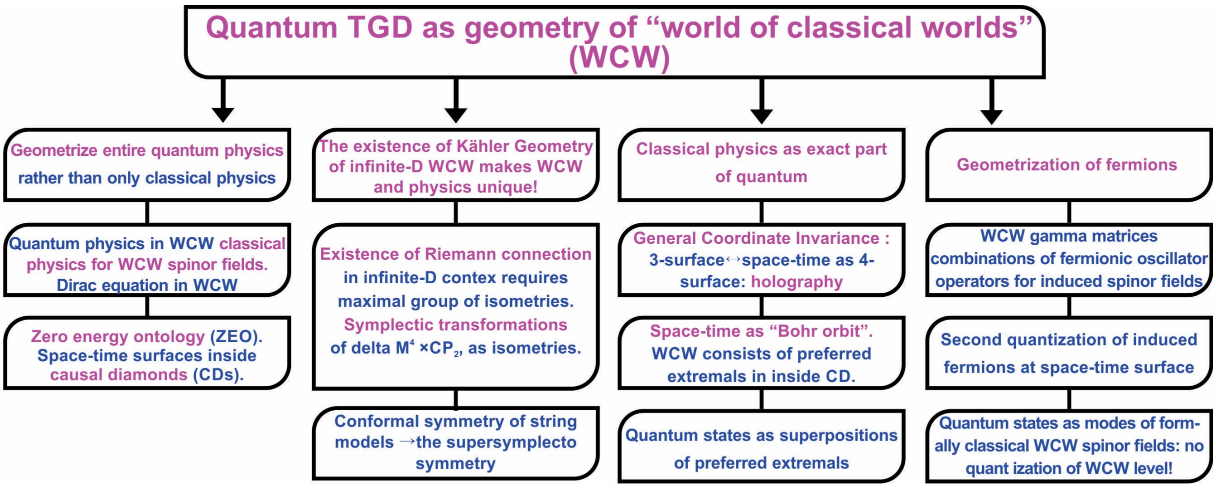

Figure 14: Geometrization of quantum physics in terms of WCW

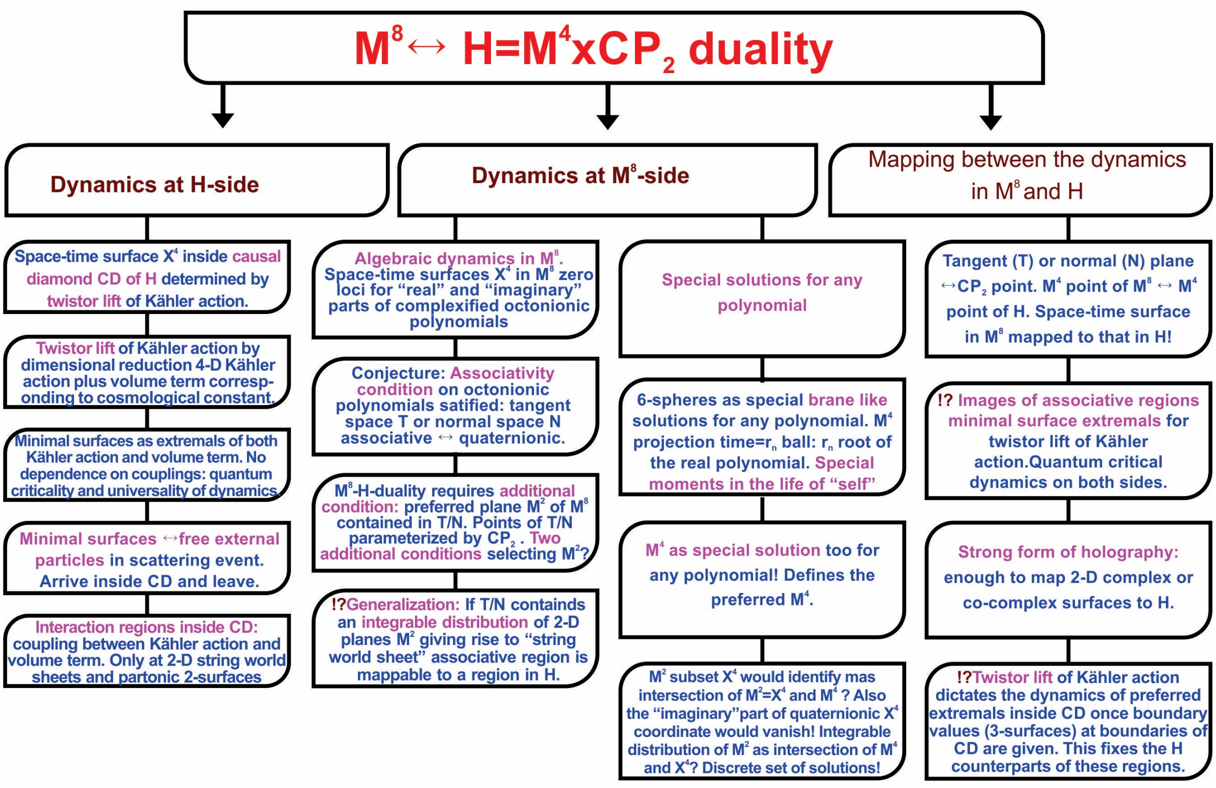

Figure 15: $M^8 - H$ duality

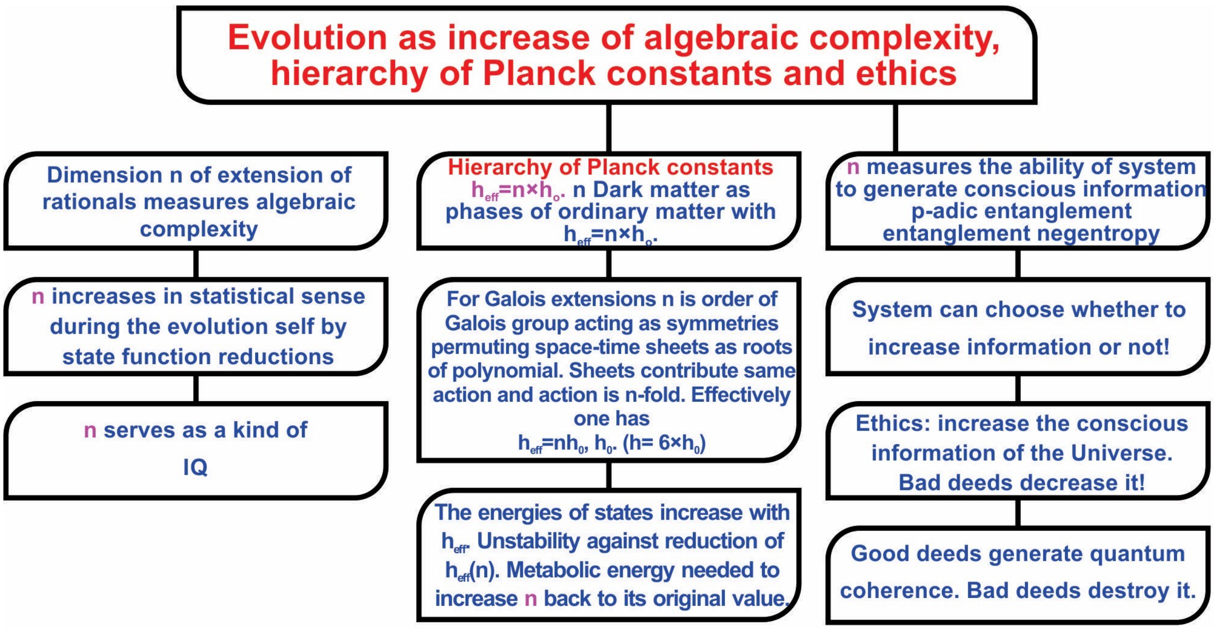

Figure 16: Number theoretic view of evolution

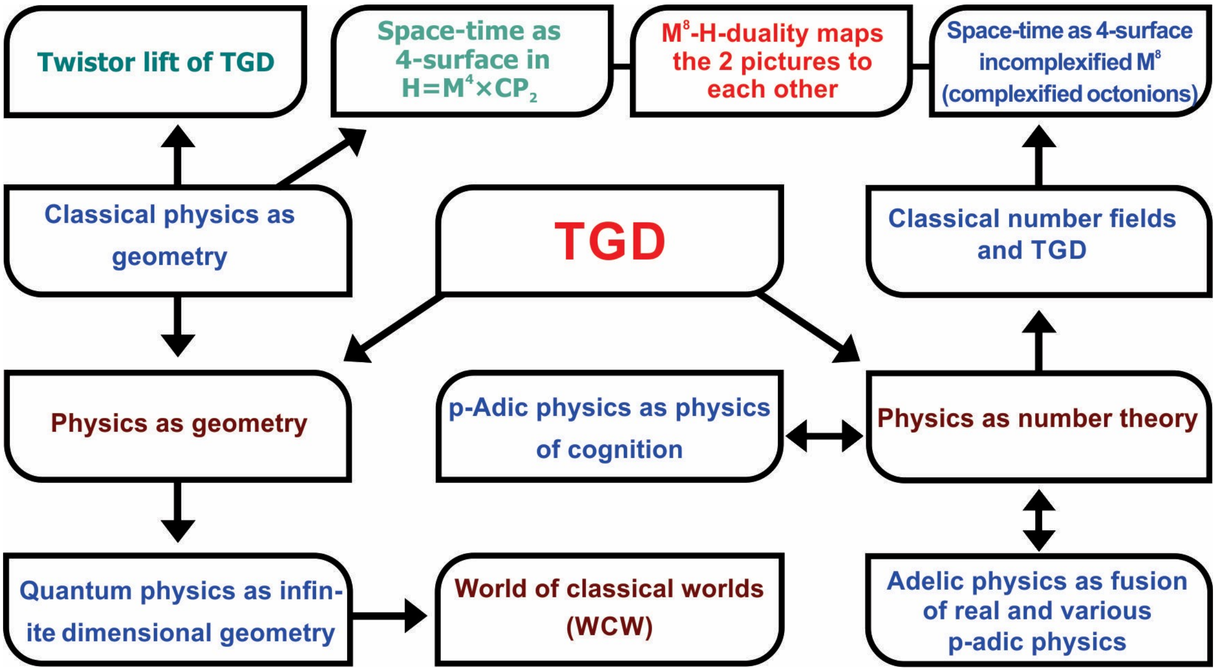

Figure 17: TGD is based on two complementary visions: physics as geometry and physics as number theory.

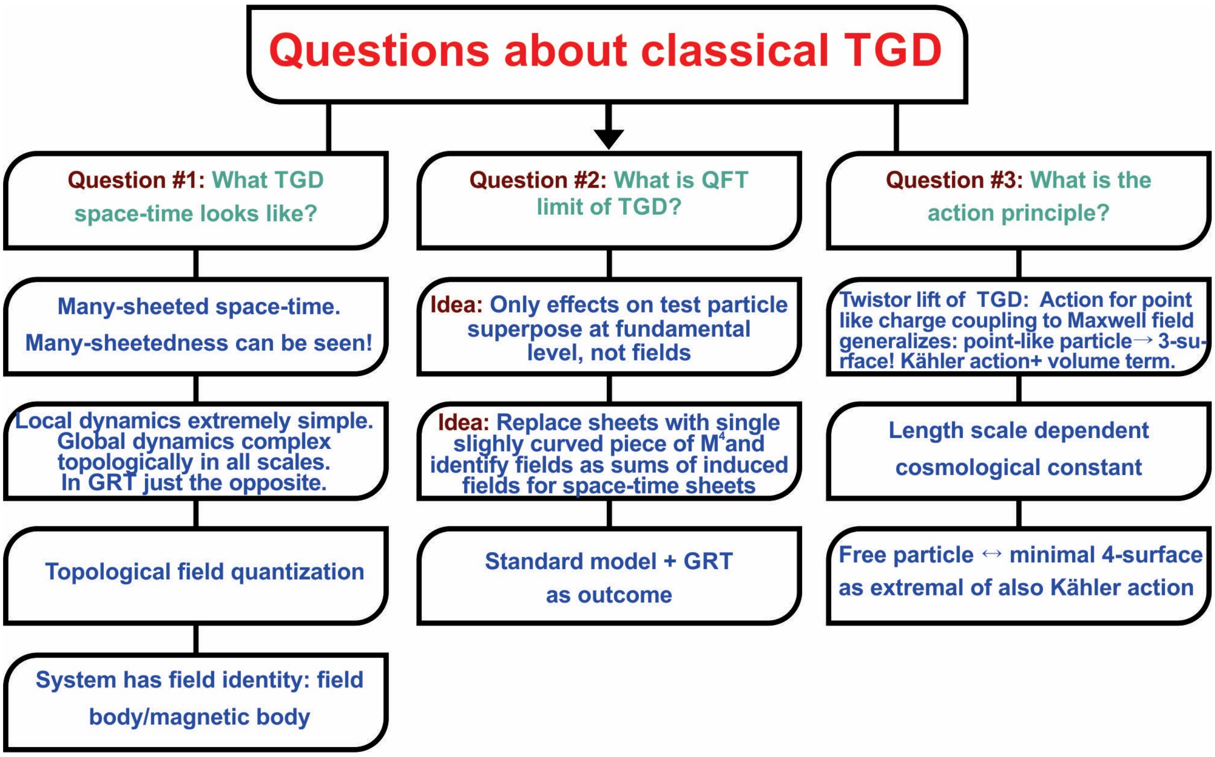

Figure 18: Questions about classical TGD.

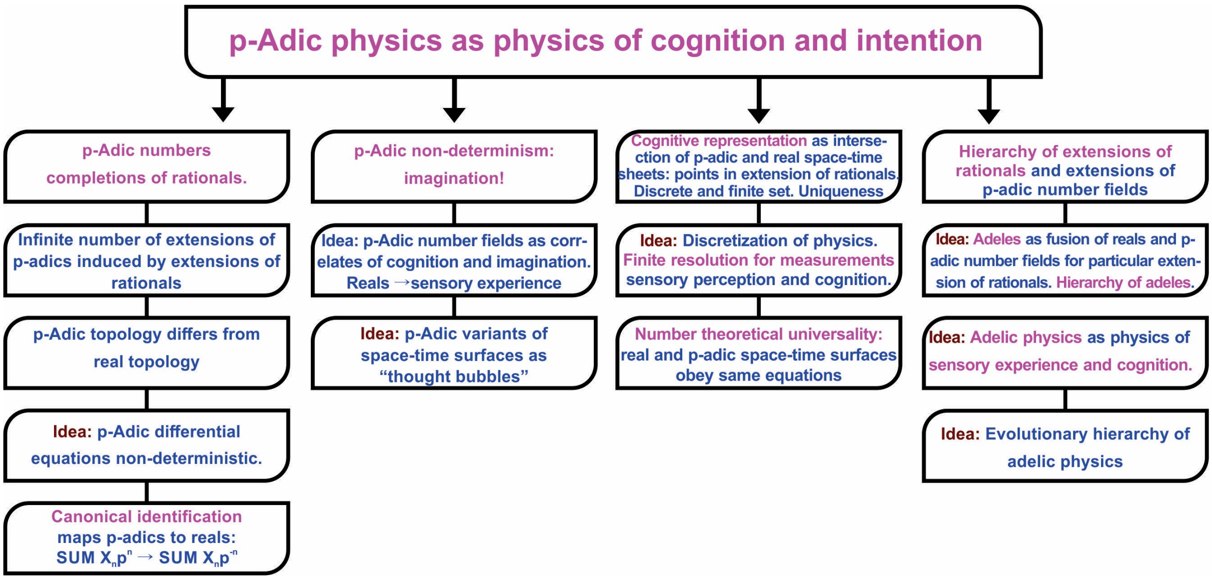

Figure 19: p-Adic physics as physics of cognition and imagination.

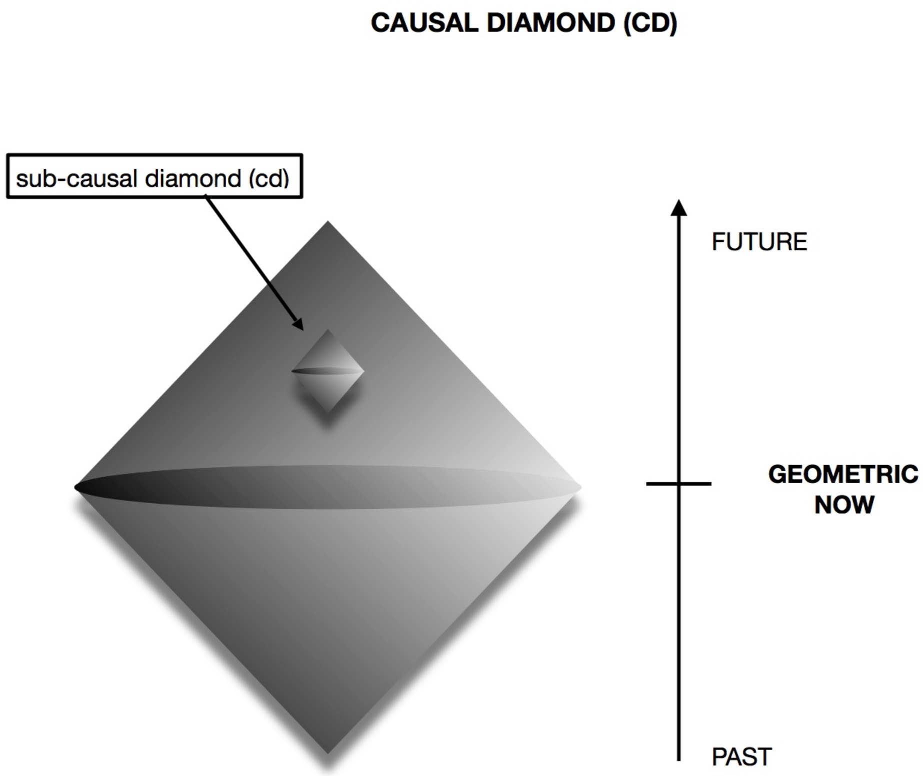

Figure 20: Causal diamond

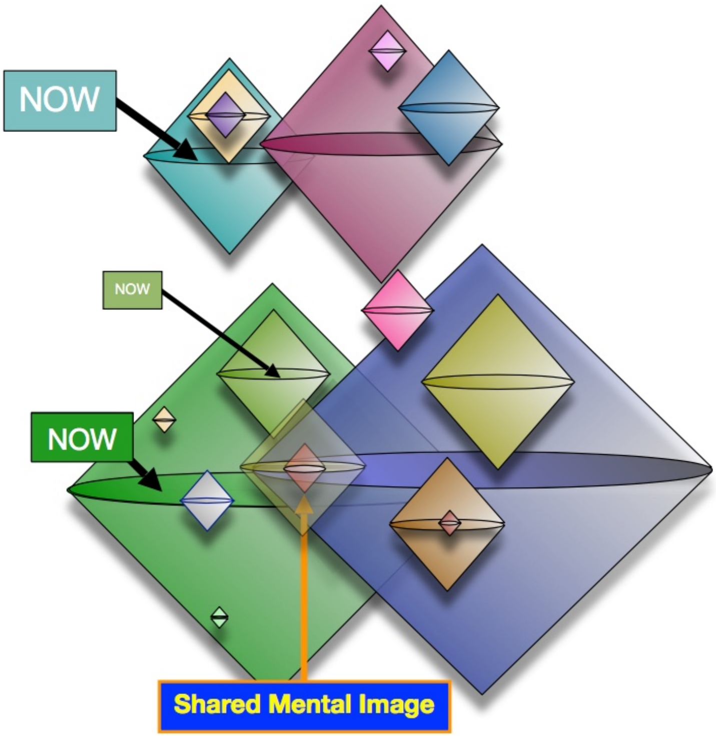

Figure 21: CDs define a fractal "conscious atlas"

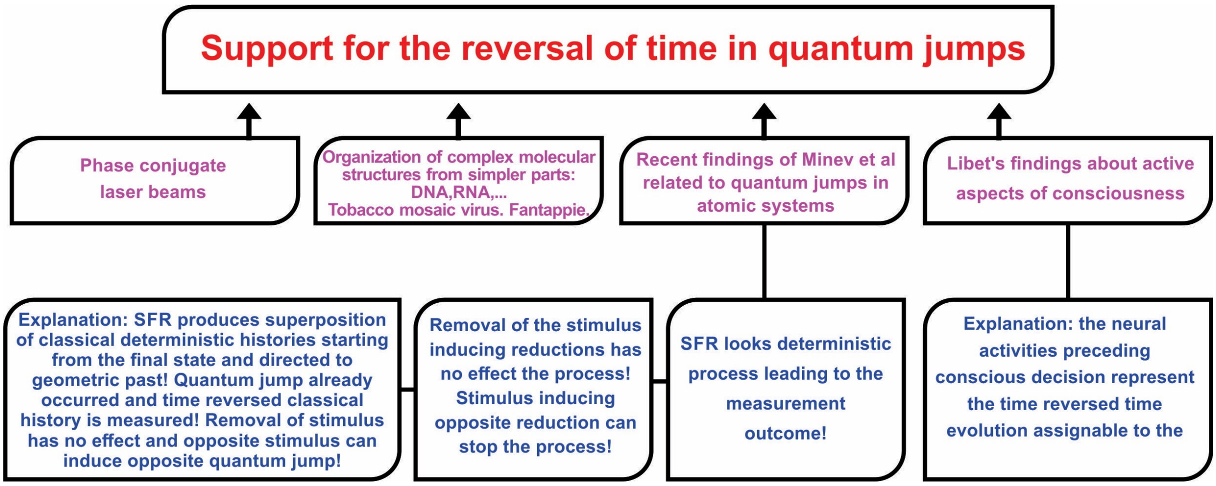

Figure 22: Time reversal occurs in BSFR

ACKNOWLEDGEMENTS

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

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

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

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

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

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

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

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

Karkkila, August 30, 2023, Finland

Matti Pitkänen

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Chapter 1

Introduction

1.1 Basic Ideas of Topological Geometrodynamics (TGD)

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

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

1.1.1 Geometric Vision Very Briefly

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

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

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

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

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

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

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

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

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

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

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

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

electromagnetic fields are nonvanishing. The correlations functions for weak fields are 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 [A2] [B14, B12, B13]), 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 [B11]) or something similar. Rather, TGD space-time is topologically non-trivial in all scales and even the visible structures of the everyday world represent non-trivial topology of space-time in the TGD Universe.

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

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

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

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

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

TGD as a Poincare Invariant Theory of Gravitation

The first approach was born as an attempt to construct a Poincare invariant theory of gravitation. Space-time, rather than being an abstract manifold endowed with a pseudo-Riemannian structure, is regarded as a surface in the 8-dimensional space $H = M^4_\times CP_2$, where M^4 denotes Minkowski space and $CP_2 = SU(3)/U(2)$ is the complex projective space of two complex dimensions [A15, A20, A9, A19].

The identification of the space-time as a sub-manifold [A16, A27] 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 and sum over the deviations of the induced metrics of the space-time sheets from Minkowski metric. Poincare invariance strongly suggests classical EP for the GRT limit in long length scales at least. One can also consider other kinds of limits such as the analog of GRT limit for Euclidian space-time regions assignable to elementary particles. In this case deformations of CP_2 metric define a natural starting point and CP_2 indeed defines a gravitational instanton with a very large cosmological constant in Einstein-Maxwell theory. Also gauge potentials of the standard model correspond classically to superpositions of induced gauge potentials over space-time sheets.

Topological Field Quantization

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

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

1.1.4 Quantum TGD as Spinor Geometry of World of Classical Worlds

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

World of Classical Worlds

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

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

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

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

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

Identification of Kähler function

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

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

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

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

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

WCW spinor fields

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

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

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

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

The role of modified Dirac action

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

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

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

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

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

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

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

1.1.5 Construction of scattering amplitudes

Reduction of particle reactions to space-time topology

Particle reactions are identified as topology changes [A24, A32, A34]. For instance, the decay of a 3-surface to two 3-surfaces corresponds to the decay $A \rightarrow B + C$. Classically this corresponds to a path of WCW leading from 1-particle sector to 2-particle sector. At quantum level this corresponds to the dispersion of the generalized Schrödinger amplitude localized to 1-particle sector to two-particle sector. All coupling constants should result as predictions of the theory since no nonlinearities are introduced.

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

Construction of the counterparts of S-matrices

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

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

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

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

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

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

The notion of M-matrix

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

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

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

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

   The M-matrices associated with CDs are obtained by a discrete scaling from the minimal CD and characterized by integer n are naturally proportional to a representation matrix of scaling: $S(n) = S^n$, where S is unitary S-matrix associated with the minimal CD [K63]. This conforms with the idea about unitary time evolution as exponent of Hamiltonian discretized to integer power of S and represented as scaling with respect to the logarithm of the proper time distance between the tips of CD.

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

1.1.6 TGD as a generalized number theory

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

The Threads in the Development of Quantum TGD

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

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

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

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

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

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

Number theoretic vision very briefly

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

1. What is the relationship of p-adic non-determinism to the classical non-determinism of the basic field equations of TGD? Are the p-adic space-time region genuinely p-adic or does p-adic topology only serve as an effective topology? If p-adic physics is direct image of real physics, how the mapping relating them is constructed so that it respects various symmetries? Is the basic physics p-adic or real (also real TGD seems to be free of divergences) or both? If it is both, how should one glue the physics in different number field together to get *the* Physics? Should one perform p-adicization also at the level of the WCW? Certainly the p-adicization at the level of super-conformal representation is necessary for the p-adic mass calculations.

2. Perhaps the most basic and most irritating technical problem was how to precisely define p-adic definite integral which is a crucial element of any variational principle based formulation of the field equations. Here the frustration was not due to the lack of solution but due to the too large number of solutions to the problem, a clear symptom for the sad fact that clever inventions rather than real discoveries might be in question. Quite recently I however learned that the problem of making sense about p-adic integration has been for decades central problem in the frontier of mathematics and a lot of profound work has been done along same intuitive lines as I have proceeded in TGD framework. The basic idea is certainly the notion of algebraic continuation from the world of rationals belonging to the intersection of real world and various p-adic worlds.

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

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

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

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

This leads to surprisingly detailed predictions and far reaching conjectures. For instance, the number theoretic generalization of entropy concept allows negentropic entanglement central for the applications to living matter (see **Fig.** `http://tgdtheory.fi/appfigures/cat.jpg` or **Fig. ??** in the appendix of this book). One can also understand how preferred p-adic primes could emerge as so called ramified primes of algebraic extension of rationals in question and characterizing string world sheets and partonic 2-surfaces. Preferred p-adic primes would be ramified primes for extensions for which the number of p-adic continuations of two-surfaces to space-time surfaces (imaginations) allowing also real continuation (realization of imagination) would be especially large. These ramifications would be winners in the fight for number theoretical survival. Also a generalization of p-adic length scale hypothesis emerges from NMP [K59].

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

Infinite primes

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

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

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

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

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

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

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

Holography in H

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

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

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

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

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

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

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

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

What could the number theoretic holography mean physically?

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

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

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

Twistor lift of the holography

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

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

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

1. The selection of $SU(3) \subset G_2$ for ordinary $M^8 - H$ duality means that the $G_{2,c}$ gauge field vanishes everywhere and the choice of color quantization axis is the same at all points of the 4-surface. The fixing of the CP_2 point to be constant at H^3 implies that the color gauge field at $H^3 \subset M^8_c$ and its image $H^3 \subset H$ vanish. One would have color confinement at the mass shells H^3_i, where the observations are made. Is this condition too strong?

2. The constancy of the G_2 element at mass shells makes sense physically and means a fixed color quantization axis. The selection of a fixed $SU(3) \subset G_2$ for entire space-time surface is in conflict with the non-constancy of G_2 element unless G_2 element differs at different points of 4-surface only by a multiplication of a local $SU(3)_0$ element, that is local $SU(3)$ transformation. This kind of variation of the G_2 element would mean a fixed color group but varying choice of color quantization axis.

3. Could one consider the possibility that the local $G_{2,c}$ element is free and defines the twistor lift of $M^8 - H$ duality as something more fundamental than the ordinary $M^8 - H$ duality based on $SU(3)_c$. This duality would make sense only at the mass shells so that only the spaces $H^3 \times CP_2$ assignable to mass shells would make sense physically? In the interior CP_2 would be replaced with the twistor space $SU(3)/U(1) \times U(1)$. Color gauge fields would be non-vanishing at the mass shells but outside the mass shells one would have G_2 gauge fields.

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

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

1.1.8 Hierarchy of Planck Constants and Dark Matter Hierarchy

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

Dark Matter as Large $\hbar$ Phases

D. Da Rocha and Laurent Nottale [E6] 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 [K92].

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 [K79, K80, K77]) support the view that dark matter might be a key player in living matter.

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

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

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

1.1.9 Twistors in TGD and connection with Veneziano duality

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

Twistor lift at space-time level

8-dimensional generalization of ordinary twistors is highly attractive approach to TGD [K108]. The reason is that M^4 and CP_2 are completely exceptional in the sense that they are the only 4-D manifolds allowing twistor space with Kähler structure [A21]. The twistor space of $M^4 \times CP_2$ is Cartesian product of those of M^4 and CP_2. The obvious idea is that space-time surfaces allowing twistor structure if they are orientable are representable as surfaces in H such that the properly induced twistor structure co-incides with the twistor structure defined by the induced metric.

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

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

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

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

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

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

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

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

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

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

   Inflation is replaced with its TGD counterpart in which the thickening of cosmic strings to flux tubes leads to a transformation of Kähler magnetic energy to ordinary and dark matter. Since the increase of volume increases volume energy, this leads rapidly to energy minimum at some flux tube thickness. The reduction of cosmological constant by a phase transition however leads to a new expansion phase. These jerks would replace smooth cosmic expansion of GRT. The discrete coupling constant evolution predicted by the number theoretical vision could be understood as being induced by that of cosmological constant taking the role of cutoff parameter in QFT picture [L42].

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 [L32]. Similar discretization would take place for momenta. Loops would vanish at the level of discretization but what would happen at the possibly existing continuum limit: does the sequence of poles integrate to cuts? Or is representation as sum of resonances something much deeper?

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

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

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

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

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

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

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

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

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

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

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

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

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

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

1.2 Bird's Eye of View about the Topics of "TGD View of Bio-Systems as Self-Organizing Quantum Systems"

This book represents the basic ideas of the TGD inspired view of quantum biology as they emerged long before the recent view of TGD was established. The material represents thereforeolder layers of TGD. I have organized the book in 3 parts.

1. In the first part of the book, the new TGD based physics proposed to be relevant to quantum biology is discussed. One key notion is dark matter as phases of ordinary matter with even very large values of effective Planck constant. Two chapters are devoted to new physics relevant to the TGD view of biosystems and to the model of high T_c super-conductivity relying strongly on the notions of quantum criticality and dark matter.

2. In the second part of the book, the notions of "massless extremal" (ME) or topological light ray, magnetic flux quantum as space-time surface, and field/magnetic body, distinguishing between TGD Universe and Maxwellian world, are introduced. The notion of a wormhole magnetic field was introduced much before the hypothesis that elementary particles have a natural identification as pairs of wormhole contacts connected by flux tubes carrying monopole flux. In the recent interpretation wormhole contact pairs would be dark variants of p-adically scaled variants of ordinary particles.

3. In the second part of the book quantum antenna hypothesis inspired by ME is discussed. Two chapters are devoted to how quantum control and coordination could be realized in the TGD Universe.

4. In the third part of the book two chapters are devoted to the TGD view of quantum self-organization in living systems. One chapter is devoted to the possible implications of the p-adic length scale hypothesis. The material is rather old and I have added a chapter about homeostasis in zero energy ontology, representing the recent views based on zero energy ontology (ZEO).

I must apologize for the fact the implications of the dark matter revolution have not been thoroughly considered in this book. Same applies to the implications of ZEO.

1.3 Sources

The eight online books about TGD [K117, K109, K86, K68, K24, K64, K45, K95] and nine online books about TGD inspired theory of consciousness and quantum biology [K105, K20, K76, K18, K42, K53, K57, K94, K104] 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.

1.3.1 PART I: THE NEW PHYSICS OF LIVING MATTER

Dark Forces and Living Matter

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

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

The weak form of electric-magnetic duality led to the identification of the long sought for mechanism causing the weak screening in electroweak scales. The basic implication of the duality is that Kähler electric charges of wormhole throats representing particles are proportional to Kähler magnetic charges so that the CP_2 projections of the wormhole throats are homologically non-trivial. The Kähler magnetic charges do not create long range monopole fields if they are neutralized by wormhole throats carrying opposite monopole charges and weak isospin neutralizing the axial isospin of the particle's wormhole throat. One could speak of confinement of weak isospin. The weak field bodies of elementary fermions would be replaced with string like objects with a length of order W boson Compton length. Electro-magnetic flux would be feeded to electromagnetic field body where it would be feeded to larger space-time sheets. Similar mechanism could apply in the case of color quantum numbers. Weak charges would be therefore screened for ordinary matter in electro-weak length scale but dark electro-weak bosons correspond to much longer symmetry breaking length scale for weak field body. Large values of Planck constant would make it possible to zoop up elementary particles and study their internal structure without any need for gigantic accelerators.

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

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

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

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

About the New Physics Behind Qualia

This chapter was originally about the new physics behind qualia. The model of qualia indeed involves a lot of new physics: many-sheeted space-time; massless extremals; magnetic and cyclotron phase transitions associated with quantum critical quantum spin glass phases of exotic super conductors at cellular space-time sheets; classical color and electro-weak gauge fields in macroscopic length scales, to name the most important ingredients. Gradually the chapter however expanded so that it touches practically all new physics possibly relevant to TGD inspired quantum biology. Various physical mechanisms are discussed in exploratory spirit rather than restricting the consideration to those ideas which seem to be the final word about quantum biology or qualia just at this moment.

Wormhole Magnetic Fields

The first version of this chapter was written for almost two decades ago and some interpretations have changed since then. It was argued that two purely TGD based concepts: topological field quantization and wormhole BE condensate are fundamental for the understanding of biosystems. There is not reason to modify this claim. The ideas about the physical interpretation of wormhole contacts have however developed since then dramatically: in the recent formulation of the theory wormhole contacts define basic building bricks of elementary particles. Hierarchy of Planck constants assigned with dark matter is second new notion and this might allow to see wormhole BE-condensates as BE-condensates of dark variants of ordinary particles.

1. Basic concepts

Quantum classical correspondence suggests that gauge charges and p-adic coupling constant should have space-time counterparts. The first problem is to define precisely the concepts like classical gauge charge, gauge flux, topological condensation and evaporation. The crucial ingredients in the model are so called CP_2 type extremals. The realization that # contacts (topological sum contacts and $\#_B$ contacts (join along boundaries bonds) are accompanied by causal horizons which carry quantum numbers and allow identification as partons leads to a solution of this problem.

The partons associated with topologically condensed CP_2 type extremals carry elementary particle vacuum numbers whereas the parton pairs associated with # contacts connecting two space-time sheets with Minkowskian signature of induced metric define parton pairs. These parton pairs do not correspond to ordinary elementary particles. Gauge fluxes through # contacts can be identified as gauge charges of the partons. Gauge fluxes between space-time sheets can be transferred through # and $\#_B$ contacts concentrated near the boundaries of the smaller space-time sheet.

It has become clear that the notion of $\#_B$ contact might require a modification. There are reasons to argue that boundary conditions do not allow space-time surfaces to have boundaries but are replaced by 2-fold coverings obtained by gluing two space-time sheets along their boundaries together. The 3-D light-like orbits of wormhole contacts at which Minkowskian signature of the induced metric changes to Euclidian, have replaced boundaries and $\#_B$ contacts could be either magnetic flux tubes with Minkowskian metric or Euclidian flux tube like regions.

2. Model for topologically quantized magnetic fields

Topological field quantization replaces classical magnetic fields with bundles of flux tubes parallel to the field lines; flux tubes are cylindrical 3-surfaces with outer boundary. In particular, *"wormhole magnetic fields"* having charged wormholes situated at the boundaries of the flux tubes as their sources, are possible and are vacuum configurations in the sense that they do not contain ordinary matter at all. Since wormholes are very light particles, they can suffer BE condensation, and the resulting structure is macroscopic quantum system.

The recent view about particles suggests that wormhole BE-condensates are BE-condensates of particle with non-standard and large value of Planck constant. Magnetic fluxes and their braiding play key role in the TGD inspired model of topological quantum computation in living manner. This suggests that wormhole magnetic fields and more general structures of the same kind could realize quantum physicist's version about the computer scientist's dream about universe consisting of Turing machines emulating each other.

3. Models for Comorosan effect, phantom DNA effect, and homeopathy

It is shown that the concept of wormhole magnetic fields suggest a model of *Comorosan effect* and *phantom DNA effect*. Homeopathy could be explained in terms of the mind-like space-time sheets mimicking the properties of the drug and left to the solution in the repeated dilution of the drug. Wormhole magnetic fields provide a quantum mechanism of control from distance, say of the control of the behavior of cell organelles by cell nucleus as well as a model for the memory of bio-system in terms of integer valued winding numbers identifiable as quantized momenta of wormhole supra currents. Wormhole magnetic fields can also represent defects of electron and neutrino super conductors and serve as a templates for the topological condensation of ordinary matter. The fact that wormhole flux tubes are *hollow* cylinders, is in nice accordance with this idea (microtubules, axonal membranes, etc. are hollow cylinders).

4. TGD inspired model for psychokinesis

A model of psychokinesis (PK) based on the concept of wormhole magnetic field is proposed. The basic philosophy is that PK is not just some isolated exotic phenomenon but only a special case of the voluntary control of bodily motions, which we all routinely perform. The only difference is that the range of voluntary control extends over the boundaries of the body in case of PK. The conclusion is that PK phenomena must involve classical long range fields, which give for bio-systems spatial extension larger than what is visible (that is hands with which to grasp on external object!). According to TGD inspired theory of consciousness, cell, and even DNA can be conscious, and perform choices. Thus the model should also provide understanding about small scale bio-control such as the (possibly voluntary!) control of the motion of cell organelles performed by cell nucleus. There is also alternative approach to the understanding of psychokinesis based on the possibility of creation of space-time sheets having negative time orientation and negative classical energy density and one could consider the possibility that poltergeist effects could involve this mechanism. Many-sheeted space-time concept makes possible also psychokinesis based on levitation: what is needed that subsystem is able to topologically condense to a sufficiently large space-time sheet carrying very weak gravitational fields.

Bio-Systems as Super-Conductors: Part I

In this chapter various TGD based ideas related to the role of super-conductivity in bio-systems are studied. TGD inspired theory of consciousness provides several motivations for this.

1. Empirical evidence for high T_c superconductivity in bio-systems

There is evidence for super-conductivity in bio-systems. DNA should be insulator but under some circumstances it becomes conductor and perhaps even high T_c quantum critical super-conductor. Also evidence for Josephson effect has been reported. The so called ORMEs patented by Hudson are claimed to behave like superconductors: unfortunately the academic world has not taken these claims seriously enough to test them. The claimed properties of ORMEs conform with high quantum critical T_c super-conductivity and superfluidity. The strange findings about the strange quantal behavior of ionic currents through cell membranes suggest the presence of ionic supra currents.

2. Model for high T_c superconductivity

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

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

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

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

3. The higher critical temperature T_{c1} corresponds to a formation local configurations of parallel spins assigned to the holes of stripes giving rise to a local dipole fields with size scale of the

order of the length of the stripe. Conducting electrons form Cooper pairs at the magnetic flux tube structures associated with these dipole fields. The elongated structure of the dipoles favors angular momentum $L = 2$ for the pairs. The presence of magnetic field favors Cooper pairs with spin $S = 1$.

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

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

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

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

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

3. The model for superconductivity in living matter

The model for high T_c superconductivity was inspired by the model of bio-superconductivity in which the flux tubes of magnetic fields are carriers of supra currents and the large value of Planck constant guarantees that gap energy and critical temperature are high enough. The transversal fluctuations of flux tubes provide the counterpart of phonons generating energy gap. Besides dark Cooper pairs also the Bose-Einstein condensates of dark bosonic ions define candidates for superconducting phases provided that the gap energies in longitudinal and transversal magnetic degrees of freedom are high enough. High enough values of Planck constant can guarantee this.

Bio-Systems as Super-Conductors: Part II

This chapter is devoted to further applications of the theory of high T_c superconductors as quantum critical superconductors involving dark matter hierarchy and large values of $h_{eff} = n \times h$. A new element is the model of cell membrane acting as Josephson junction: at microscopic transmembrane proteins would define Josephson junctions. The theory is applied to explain the strange findings about ionic currents through cell membrane, and the possibility that superconductivity and Bose-Einstein condensates are involved with atmospheric phenomena is considered.

1. Strange behavior of cellular water and quantal ionic currents through cell membrane

The fact that cellular water does not leak out of cell in a centrifugal force suggests that some fraction of water inside cell is in different phase. One explanation is that the nuclei of water inside cell are in doubly dark phase whereas electrons are in singly dark phase (having Compton length of 5 nm and perhaps directly "visible" using day technology!) as indeed predicted by the model of high Tc superconductivity. This conceptual framework could explain various findings challenging the notions of ionic pumps.

The empirical findings challenging the notions of ionic pumps and channels, nicely summarized by G. Pollack in his book, provide a strong support for the notions of many-sheeted space-time and ionic super-conductivity.

1. The selectivity of the cell membrane implies that channels cannot be simple sieves and there must be complex information processing involved.

2. The needed number of pumps specialized to particular ions is astronomical and the first question is where to put all these channels and pumps. On the other hand, if the cell constructs the pump or channel specialized to a given molecule only when needed, how does it know what the pump looks like if it has never seen the molecule? The needed metabolic energy to achieve all the pumping and channelling is huge. Strangely enough, pumping does not stop when cell metabolism stops.

3. One can also wonder why the ionic currents through cell membrane look quantal and are same through cell membrane and silicon rubber membrane.

These observations suggest strongly the presence non-dissipative ionic currents and quantum self-organization. The TGD based explanation would be in terms of high T_c electronic and possibly even ionic superconductivity associated with cell membrane made possible by the large h_{eff} phase for nuclei and electrons in the interior of cell. The model for electronic Cooper pairs as pairs of large h_{eff} electrons at parallel magnetic flux tubes with same (opposite) direction of magnetic field and in $S = 1$ ($S = 0$) state generalizes.

The empirical input also supports a view about homeostasis as a many-sheeted ionic flow equilibrium controlled by larger space-time sheets with the mediation of massless extremals (MEs) serving as space-time correlates for Bose-Einstein condensates of massless bosons (also of scaled down dark electro-weak bosons and gluons).

In the proposed picture one could understand how extremely low densities of ions and their supra currents can control much higher ion densities at the atomic space-time sheets. The liquid crystal nature of the bio-matter is crucial for the model. This vision allows also much better understanding of the effects of ELF em fields on bio-matter. Also the effects of homeopathic remedies and acupuncture known to crucially involve electromagnetic frequency signatures of chemicals can be understood if homeostasis is based on many-sheeted ionic flow equilibrium.

2. Two models of cell membrane

TGD inspires two views about cell membrane: the wiews need not be contradictory. For the first model cell is far from vacuum extremal, for the second model nearly vacuum extremal with classical Z^0 fields in key role.

1. There are several constraints on the first model coming from the TGD based identification of bio-photons as energy conserving decay products of dark photons and one ends up to a new view about metabolism and gneralization to of the notion of Josephson junction so that Josephson energy includes besides electrostatic energy also the difference of cyclotron energies at two sides of the membrane. It seem that that the first model might be enough when generalized along lines inspired by Pollack's findings about the fourth phase of water.

2. It has been clear from the beginning that the nearly vacuum extremals of Kähler action could play key role key role in living systems. The reason is their criticality making them ideal systems for sensory perception. These extremals carry classical em and Z^0 fields related to each other by a constant factor and this could explain the large parity breaking effects characterizing living matter. The assumption that at least some cell membranes are nearly vacuum extremals and that nuclei can feed their Z^0 charges to this kind of space-time sheets (not true for atomic electrons) in living matter leads to a modification of the model for the cell membrane as Josephson junction. Also a model of photoreceptors explaining the frequencies of peak sensitivity as ionic Josephson frequencies and allowing the dual identifications Josephson radiation as biophotons (energies) and EEG radiation (frequencies) emerge since the values of Planck constant can be very large. Contrary to the original believe, this model does not require non-standard value of Weinberg angle and this model and first model allow a hybrid.

3. Bose-Einstein condensates at magnetic flux quanta in astrophysical length scales

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

1. There are several levels of dynamics. In topological condensation the internal dynamics of ions is unaffected and h_{eff} has the ordinary value. For instance, the formation of Cooper pairs involves dynamics at $k_d = 24 = 151 - 127$ level of dark matter hierarchy if one assumes that electrons and Cooper pairs have size given by the cell membrane thickess $L(151)$. Also the dynamics of ionic Cooper pairs remains unaffected in the topological condensation to magnetic flux quanta obeying $k_d > 24$ dynamics.

2. Cyclotron energies scale as as h_{eff} so that for a sufficiently high value of k_d thermal stability of cyclotron states at room temperature is achieved for a fixed value of B. Same applies to spin flip transitions in the recent scenario. The model for EEG based on dark matter hierarchy involves the hypothesis that EEG quanta correspond to Josephson radiation with energies in the visible and UV range and that they produce in the decay to ordinary photons either bunches of EEG photons or visible/UV photons. This identification allows to deduce the value of k_d when the frequency of the dark photon is fixed. The Mersenne hypothesis for the preferred p-adic length scales and values of Planck constants leads to very precise predictions.

3. Cyclotron energies $E = (h_{eff}/2\pi) \times ZeB/Am_p$ are scaled up by a factor $r = 2^{k_d}$ from their ordinary values and for 10 Hz cyclotron frequency are in the range of energies of visible light for $k_d = 46$.

4. These B-E condensates might be favored by the large negative spin interaction energies of spins with the magnetic field (proportional to h_{eff}) so that spontaneous magnetization of the magnetic body becomes possible. This kind or process would make possible for the system to gain energy and angular momentum by feeding charged particles to its magnetic body.

4. The model of ionic superconductivity

The model of ionic superconductivity is based on same mechanism as the electron one.

The general idea is that magnetic flux tubes are carriers of dark charged particles including ions and electrons. Usually magnetic field tends to destroy Cooper pairs since it tends to flip the spins of electrons of pair to same direction. In TGD flux quantization comes in rescue and magnetic fields favor the formation of Cooper pairs. If one has two parallel flux tubes with opposite directions of magnetic fluxes with large value of $h_{eff} = n \times h$, $S = 0$ Cooper pairs with even $L \geq 2$ are favored. This situation is encountered in systems near antiferromagnetic phase transition in small scales leading to formation of sequences of flux loops carrying Cooper pairs. Macroscopic super-conductivity results when the loops are reconnected to two long flux tubes with opposite fluxes. If the magnetic fluxes have same sign, $S = 1$ Cooper pairs with odd $L \geq 1$ are favored.

This model applies to both electrons and fermionic ions and if the proposal that h_{eff} is proportional to the mass of ion, it predicts same binding energies for all Cooper pairs as their spin-spin interaction energy. This hypothesis predicts universal spectrum of bio-photons energies if they result from dark photons and is motivated by the identification of gravitational Planck constant with h_{eff}. In this case binding energies would be in eV range and much above thermal energy at room temperature.

5. Atmospheric phenomena and superconductivity

There is a considerable evidence that various electromagnetic time scales associated with the atmospheric phenomena correspond to those associated with brain functioning. If magnetic sensory canvas hypothesis holds true, this is just what is expected. In this section these phenomena are considered in more detail with the aim being to build as concrete as possible vision about the dynamics involving the dark matter Bose-Einstein condensates at super-conducting magnetic magnetic flux quanta. A new element is the assumed presence of cell membrane like structures near vacuum extremals. If the potentials differences involved are same order of magnitude as in the case of cell membrane, the luminous phenomena can be understood in terms of effects caused by Josephson radiation at visible and UV frequencies.

Tornadoes and hurricanes provide the first example of self-organizing systems for which Bose-Einstein condensates of dark matter at magnetic and Z^0 magnetic flux quanta might be of relevance. Auroras represent a second phenomenon possibly involving supra currents of Cooper pairs and of exotic ions. Lightnings, sprites and elves might also involve higher levels of dark matter hierarchy. p-Adic length scale hypothesis and the hierarchy of Planck constants provide a strong grasp to these far from well-understood phenomena and allow to build rather detailed models for them as well as to gain concrete understanding about how dark matter hierarchy manifests itself in the electromagnetic phenomena at the level of atmosphere.

1.3.2 PART II: QUANTUM ANTENNA HYPOTHESIS

Quantum Antenna Hypothesis

So called MEs (MEs or topological light rays) are non-vacuum extremals of both Kähler action and the EYM action serving as effective action of the theory. These extremals have cylindrical geometry and are carriers of purely classical vacuum currents and Einstein tensor, which are both light like. These vacuum currents generate coherent states of photons and gravitons with frequencies coming as multiples of the basic frequency determined by the length of the microtubule. They can also carry Bose-Einstein condensates of massless particles. It is proposed that microtubules and other linear structures could act as quantum antennae so that coherent light would be for brain same as radiowaves for us. MEs associated with axonal microtubules or axons themselves could serve as waveguides for the photons of coherent light and realize the notion of neural window abstracted from the paradigm of holographic brain. Vacuum currents could be also behind the ability of the biosystems to form representations of the external world.

There is indeed evidence for the quantum antenna hypothesis: some monocellulars are known to possess primitive microtubular vision, biophotons of Popp could could be generated by MEs and the observations of Callahan support the view that odour perception of insects relies on maser-like emissions by the odour molecules. The coherent light emitted in sonoluminescence could be generated by light-like vacuum currents associated with regions with size given roughly by the diameter of microtubule when vapour-to-liquid phase transition occurs at the final stage of the bubble collapse. Also the observed direct transformation of kinetic energy of fluid motion to chemical energy could involve generation of MEs.

The light-like boundaries of MEs might not be allowed by boundary conditions: MEs could appear as pairs glued together along boundaries or as a similar pair of ME and magnetic flux tube. If the boundaries are however possible, they have the same miraculous conformal properties as the boundary of future lightcone and MEs also allow holography in the sense of quantum gravity and string models and there are good hopes to generalize the construction of the WCW geometry and quantum TGD to take into account the classical non-determinism of Kähler action. MEs provide a justification for the intuition that the supersymplectic and superconformal symmetries of the lightcone boundary $\delta M^4_+ \times CP_2$, which are cosmological symmetries, generalize to approximate macroscopic symmetries acting on the light-like boundaries of the spacetime sheets inside future lightcone and broken only by quantum gravity. Supersymplectic symmetries almost-commute with Poincare symmetries and the gigantic almost-degenerate supersymplectic multiplets defined by genuinely quantum gravitational state functionals in the "world of worlds" correspond in a well-defined sense to higher abstraction level expected to be crucial for understanding consciousness. MEs are also tailor-made for quantum holography and teleportation. Quantum holography conceptualization inspires much more detailed views about how biosystems process information and how this information becomes conscious.

Quantum Control and Coordination in Bio-Systems: Part I

The basic dynamical aspects of the biological system relate to coordination and control. Coordination is involved with almost automatic and predictable activities involving no volition whereas control involves volition and non-predictability. A basic examples of coordination and control are EEG and nerve pulse respectively. Various motor activities are good examples of a control involving macroscopic changes of the shape of the organ. The great challenge is to identify the quantum correlates of coordination and control.

The vision about living matter as consisting of a fractal hierarchy of MEs controlling a fractal hierarchy super-conducting magnetic flux tube structures in turn controlling ordinary matter at atomic space-time sheets via many-sheeted ionic flow equilibrium provides a very promising approach for modelling living matter. MEs interact with magnetic superconductors via magnetic induction by inducing supra-currents, by acting as Josephson junctions between magnetic flux tubes, and by inducing magnetic transitions.

The fact (discovered much later than the first version of the chapter was written) that TGD predicts infinite hierarchy of dark matters defining scaled down copies of color and electro-weak physics generalizes this picture dramatically and means that dark matter becomes the quintessential component of living systems. The predicted spectrum for the values of Planck constant conforms with quantum criticality since Kähler function does not depend on $\hbar$ and long range fluctuations at quantum criticality can be also interpreted as fluctuations in the value of $\hbar$ appearing only in the construction of quantum states and making possible macroscopic quantum coherence.

The original proposal was that the formation of join the along boundaries bonds between the space-time sheets possibly representing different levels of the self hierarchy could be the basic mechanism of control and coordination. In the updated model join along boundaries are replaced by magnetic flux tubes with the motivation coming from the fact that boundary conditions might not allow boundaries at all! Boundaries would be replaced by boundaries of Minkowskian regions at which the signature of the induced metric changes from Minkowskian to Euclidian) with Euclidian region defining the space-time sheet assignable to even macroscopic system.

The interpretation as a prerequisite for bio-feedback, understood in very general sense, is very suggestive. The presence of join along boundaries bonds makes possible transfer of various charge particles between space-time sheets in question and the resulting system is very similar to two weakly coupled super conductors connected by Josephson junctions. This suggests that that super currents and Josephson currents between the space-time sheets are crucial for the coordination, which could be identified as deterministic quantum time development without quantum jumps.

Any harmonic perturbation with some magnetic transition frequency can induce magnetic quantum transitions and even magnetic quantum phase transitions. An attractive identification for this process is as basic tool of quantum control tool so that the resonance frequency appears as control parameter "waking up" subself at its critical value. Critical frequencies correspond to the magnetic and Z^0 magnetic cyclotron frequencies in the model of super conductor relying on the presence of weak magnetic or Z^0 magnetic field (magnetic field guarantees effective one-dimensionality of the super conductor and implies finite gap energy in TGD framework). Cyclotron frequency hypothesis has had rather dramatic success and leads to a rather detailed picture about brain as a macroscopic quantum system.

This general picture is applied at various levels. A general model for weakly coupled super conductors is constructed and simple models for various control tools like comparison circuits, biological clocks and alarm clocks, feature detectors and novelty detectors are sketched. This model of quantum control is applied in some particular cases.

Decade later this picture has become considerably more detailed with more detailed model for how dark low frequency photons are used in living system the basic tool of control and coordination. In particular, the hypothesis that dark photons decay to ordinary photons with visible and UV energies identifiable as biophotons has emerged.

Quantum Control and Coordination in Bio-Systems: Part II

This chapter is devoted to the aspects of quantum control and coordination involving the intentional action of the magnetic body and classical em and possibly Z^0 fields (as suggested by large parity breaking effects in living matter). The previous chapters are warmly recommended in order to get an overall view about basic philosophy and ideas. The general understanding of the dynamics of Kähler action provides a considerable light to how topologically quantized induced Kähler field defines templates for bio-structures and for their self-organized dynamics with self-organization understood in 4-D sense selecting 4-D time evolution patterns. Time mirror mechanism is the most convincing mechanism for realizing intentional action discovered hitherto. Also the possible role of classical Z^0 force in condensed matter and bio-chemistry is discussed.

In the original version of the chapter I did not yet know anything about zero energy ontology (ZEO), the hierarcy of Planck constants defining dark matter hierachy nor the notion of magnetic body carrying dark matter. ZEO provides justification and precise definition what negative energy signals propagating into past are. The notion of magnetic body containing macroscopic quantum phases responsible for bio-control, and the fact that dark matter would reside at magnetic flux tubes, motivate the hypothesis that living matter is actually dark matter with the large value of Planck constant determining the characteristic time and length scales of the conscious system.

1.3.3 PART III: SELF-ORGANIZATION IN LIVING MATTER

Quantum Theory of Self-Organization

Quantum theory of self-organization based on the idea that quantum jump serves as the basic step of self-organization, is represented. The notion of self and the identification of self as the fundamental statistical ensemble gives totally new meaning for the concept of self-organization as a generation of hierarchies of selves.

Zero modes of the WCW geometry, whose existence derives from the generalization of point like particle to 3-surface, provide universal, nonlocal order parameters and the emergence of the new level of self-organization occurs through phase transition like process as also in Haken's theory. The fact that quantum jumps involve localization in zero modes means that the sequence of quantum jumps means hopping in zero modes characterizing the classical aspects of the spacetime geometry.

The recent view about quantum TGD involves several incredients which allow to considerably sharpen and enrich the original view about self-organization. In zero energy ontology (ZEO) all space-time sheets are "mind-like" space time sheets assigned with cognition. Number theoretical Shannon entropy having also negative values and making sense for rational or at most algebraic entanglement probabilities allows negentropic entanglement so that Negentropy Maximization Principle (NMP) in this case favors formations of larger coherent structures. One could say that intelligent life resides in the intersection of real and various p-adic worlds much like rationals represent islands of order in the sea of chaos defined by generic real or p-adic numbers. Dark matter hierarchy with levels partially labelled by the value of Planck constant brings in dark matter playing a key role in biological self organization. Consistency of NMP with standard quantum measurement theory allows only entanglement characterized by a density matrix proportional to unit matrix. Entanglement matrix proportional to a unitary matrix associated with quantum computation defines this kind of density matrix.

The quantum version of Haken's theory of self-organization is proposed. Spin glass analogy means that "energy" landscape has fractal valleys inside valleys structure: this structure is important for understanding long term memories. A crucially important aspect of the quantum self-organization is the Darwinian selection of very few asymptotic self-organization pattterns by dissipation which explains the selection of both genes and memes: this selection provides royal road to the understanding of various miraculous feats performed by living matter.

In ZEO self-organization takes place for 4-D spatio-temporal patterns since 3-surfaces are pairs of space-like surfaces at the boundaries of CD and maxima of Kähler function are selected in the process. This brings in totally new and highly non-trivial aspect. These temporal patterns correspond to behaviors and functions in living matter. One could understand complex miracle the generation of complex spatio-temporal patterns such as morphogenesis as a sequence of 4-D trials. In this framework evolution in given time scale is not an outcome of random choice followed by selection as Darwinian dogma states.

The comparison with Rupert Sheldrake's concepts of morphic field and morphic resonance leads to interesting ideas about how learning at the level of species could occur quantum-mechanically. The 4-D character of self-organization makes learning a basic spontaneously occurring process: each self is by definition a learning entity. For instance, the phenomenon of biofeedback suggests that self could quite generally effectively act on its subselves. In ZEO all quantum states have properties allowing to interpret them as memes or quanta of morphic fields and the challenge is to find their biological counterparts. DNA as topological quantum computer hypothesis suggest the identification of the biological memes as topological quantum computer programs assignable to the intronic portion of the genome and coded also by nerve pulse patterns. The notion of magnetic body as intentional agent leads to a concrete model for the morphic resonance as a transfer of topological quantum computation programs between separate brains with the mediation of the personal magnetic bodies and the magnetic body of Mother Gaia using EEG like communications. The model explains also "alike likes alike" rule. Spatio-temporal evolution of the magnetic body could serve as template for the evolution of dark and ordinary matter associated with it.

Biological Realization of Self Hierarchy

Self-hierarchy is the basic prediction of the TGD inspired theory of consciousness and the biological realization of the self-hierarchy is the basic theme of this chapter. Space-time sheets, in particular mind like space-time sheets having finite temporal duration and providing cognitive representation of the material world, are geometrical correlates of selves and biological self hierarchy reduces geometrically and topologically to the hierarchy of space-time sheets. Crucially involved is the notion of the topological field quantization, which among other things implies that photons have as their classical geometrical correlates so called topological field quanta. One interpretation for the topological field quanta of em field is as classical/quantal coherence regions of classical/quantum em field and electromagnetic (em) fields and their topological field quanta are expected to be especially important in bio-systems. One can assign vacuum quantum numbers to topological field quanta and these quantum numbers are expected to be carriers of a biologically relevant information.

What self actually is in quantum sense, has taken long time to understand. The realization that in zero energy ontology (ZEO) sequences of repated quantum jumps leave only the second half of zero energy state invariant but change the other one led to the identification of self as the sequence of the quantum jumps reducing the state to the same boundary of causal diamond (CD). This also answers basic questions about the relationship of geometric and subjective time.

In principle the self hierarchy starts already at elementary particle level but the atomic length scale serves as a natural length scale for length scale at which biological relevant part of the self-hierarchy starts.

1. The assumption that various bio-molecules are selves allows to understand the miraculous abilities of living systems as outcome of quantum self-organization process in which dissipation selects very limited repertoire of self-organization patterns identifiable as survivors in Darwinian selection. For instance, one can understand protein folding and DNA replication as self-organization processes. The 4-D character of self-organization implies that the most probable outcomes are pairs of 3-surfaces at boundaries of causal diamond defining spatio-temporal rather than only spatial pattern. This allows totally new view about morphogenesis and development of skills.

2. The fact that bio-systems are liquid crystals, makes them ideal for the realization of the self hierarchy. The reason is that liquid crystals have ability to self-organize to very complicated structures and are ideal for communication purposes: for instance, mechanical signals can be coded to electric signals and vice versa. Liquid crystals are also electrets: the presence of electric fields is indeed an important prerequisite of cognition in TGD as discussed in the

chapter "Information and consciousness". In fact, one could identify various bio-structures such as micro-tubuli, cell organelles and cells as generic outcomes of the self-organization of the liquid crystals. An especially important level of the self hierarchy is provided by collagen networks which could give rise to what might be called "body consciousness". Central nervous system is only one, although very important level in the self hierarchy, and TGD approach allows to understand why this is the case.

3. p-Adic length scale hypothesis allows quantitative grasp to the structure of the self hierarchy and one can build general picture about how various p-adic length scales emerged during the evolution. In particular, one can identify various p-adic length scales associated with the brain.

4. One level of the self hierarchy corresponds to the topological field quanta of ELF em fields associated with EEG. ELF (extremely low frequency) em fields are known to have dramatic effects on living matter and brain and the origin of these effects is poorly understood. A simple argument based on Uncertainty Principle leads to the conclusion that ELF photons in 10 Hz frequency range correspond to topological field quanta of size of entire Earth. This leads to a rather dramatic conclusion that our biological body is only a dip of an iceberg and we are much more than our neurons. The most important levels in our personal self hierarchy contains levels are of size of Earth! Support for this picture come from the quantitative success of the scenario: one can immediately understand various important neuro time scales in terms of the cyclotron frequencies of various charged particles in Earth's magnetic field.

5. Each bio-structure is accompanied by a topologically quantized magnetic field defining corresponding magnetic body and these magnetic bodies form a hierarchy. Magnetic bodies could serve as intentional agents, as templates for the formation of various biological control circuits crucial for homeostasis and biological information processing, define the basic structure making possible metabolism with universal metabolic energy currencies, and could even define what might be called Nature's own bio-laboratory.

6. The magnetic flux structures associated with body could be of crucial importance for understanding human consciousness. For instance, eyes generate magnetic fields. Also brain, in particular pineal gland (the "third eye" of mystics and the seat of soul for Descartes), contains magnetic materials. Corresponding magnetic transition frequencies correspond to time scales relevant for the self narrative in human time scales. Perhaps these higher levels of magnetic self hierarchy could relate with NDE experiences and represent structures surviving in biological death.

Possible Role of p-Adic Numbers in Bio-Systems

In this chapter p-adic physics, p-adic length scale hypothesis, and the special features of p-adic numbers are discussed from the point of view of biosystems. The identification of p-adic physics as physics of cognition tentatively identified as a cognitive simulation of real physics is the basic philosophical quide line. Second key idea is that living matter in very general sense lives in the intersection of real and p-adic worlds making among other things possible negentropic entanglement so that Negentropy Maximization Principle drives the formation of increasingly larger structures with negentropic entanglement.

The justification of the p-adic length scale hypothesis in zero energy ontology (ZEO) is discussed and the application of the hypothesis is discussed: both primary p-adic length scales and secondary p-adic length scales emerging naturally in zero energy ontology are discussed and it is found that the secondary p-adic scales assignable to elementary particles are in general macroscopic so that a connection between elementary particle physics and macroscopic physics suggests itself. Small-p p-adicity is also highly attractive idea and it is demonstrated that dark matter hierarchy characterized by hierarchy of Planck constants provides a first principle realization of this idea.

The characteristic features of p-adic physics are due to p-adic ultra-metricity, p-adic non-determinism, and to some exotic properties of p-adic probability and are expected to characterize also cognition. It is however too early to take too strong views concerning the interpretation of p-adics. Therefore also speculative ideas about the role of p-adic numbers in biology, which are only marginally consistent with the cognitive interpretation, are discussed in the sequel.

Also some speculations about possible role of so called exotic representations of superconformal algebra are included. These speculations rely heavily on the assumption that canonical correspondence between p-adic and real masses holds true in full generality. The prediction is the existence of a hierarchy of p-adic states for which p-adic masses have extremely small real counterparts whereas the corresponding real states have super-astronomical masses. These strange states have huge degeneracies and the original speculation was that they are crucial for the understanding of biological life. Later however came the realization that the states of the super-symplectic representations associated with the light-like boundaries of massless extremals (MEs) have also gigantic almost-degeneracies. In particular, there is no need to assume the highly questionable p-adic–real correspondence at the level of masses for them. Therefore the cautious conclusion is that biology can do without the exotic super-conformal representations.

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.

Part I

THE NEW PHYSICS OF LIVING MATTER

Chapter 2

Dark Forces and Living Matter

2.1 Introduction

The unavoidable presence of classical long ranged weak (and also color) gauge fields in TGD Universe has been a continual source of worries for more than two decades. The basic question has been whether electro-weak charges of elementary particles are screened in electro-weak length scale or not. The TGD based view about dark matter assumes that weak charges are indeed screened for ordinary matter in electro-weak length scale but that dark electro-weak bosons correspond to much longer symmetry breaking length scale.

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

The weak form of electric-magnetic duality led to the identification of the long sought for mechanism causing the weak screening in electroweak scales. The basic implication of the duality is that Kähler electric charges of wormhole throats representing particles are proportional to Kähler magnetic charges so that the CP_2 projections of the wormhole throats are homologically non-trivial. The Kähler magnetic charges do not create long range monopole fields if they are neutralized by wormhole throats carrying opposite monopole charges and weak isospin neutralizing the axial isospin of the particle's wormhole throat. One could speak of confinement of weak isospin. The weak field bodies of elementary fermions would be replaced with string like objects with a length of order W boson Compton length. Electro-magnetic flux would be feeded to electromagnetic field body where it would be feeded to larger space-time sheets. Similar mechanism could apply in the case of color quantum numbers. Weak charges would be therefore screened for ordinary matter in electro-weak length scale but dark electro-weak bosons correspond to much longer symmetry breaking length scale for weak field body. Large values of Planck constant would make it possible to zoop up elementary particles and study their internal structure without any need for gigantic accelerators.

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

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

In its original form this chapter was an attempt to concretize and develop ideas related to dark matter by using some experimental inputs with emphasis on the predicted interaction between the new nuclear physics and condensed matter. As the vision about dark matter became more coherent and the nuclear string model developed in its recent form, it became necessary to update the chapter and throw away the obsolete material. I dare hope that the recent representation is more focused than the earlier one.

2.1.1 Evidence For Long Range Weak Forces And New Nuclear Physics

There is a lot of experimental evidence for long range electro-weak forces, dark matter, and exotic nuclear physics giving valuable guidelines in the attempts to build a coherent theoretical scenario.

Cold fusion

Cold fusion [C8] is a phenomenon involving new nuclear physics and the known selection rules give strong constraints when one tries to understand the character of dark nuclear matter. The simplest model for cold fusion found hitherto is based on the nuclear string model [L3]. [L3] and will be taken as the basis of the considerations of this chapter. Also comparisons with the earlier variant of model of cold fusion [K97] will be made in the section about cold fusion.

Large parity breaking effects

Large parity breaking effects in living matter indicate the presence of long ranged weak forces, and the reported nuclear transmutations in living matter [C6, C22] suggest that new nuclear physics plays a role also now. For instance, the Gaussian Mersennes $(1+i)^k-1$ for $k = 113, 151, 157163, 167$ could correspond to weak length scales and four biologically important length scales in the range 10 nm-25 μm, which seem to relate directly to the coiling hierarchy of DNA double strands.

Anomalies of the physics of water

The physics of water involves a large number of anomalies and life depends in an essential way on them. As many as 41 anomalies are discussed in the excellent web page “Water Structure and Behavior” of M. Chaplin [D53]. The fact that the physics of heavy water differs much more from that of ordinary water as one might expect on basis of different masses of water molecules suggests that dark nuclear physics is involved.

1. The finding that one hydrogen atom per two water molecules remain effectively invisible in neutron and electron interactions in atto-second time scale [D53, D50] suggests that water is partially dark. These findings have been questioned in [D57] and thought to be erroneous in [D32]. If the findings are real, dark matter phase made of super-nuclei consisting of protons connected by dark color bonds could explain them as perhaps also the clustering of water molecules predicting magic numbers of water molecules in clusters. If so, dark nuclear physics could be an essential part of condensed matter physics and biochemistry. For instance, the condensate of dark protons might be essential for understanding the properties of bio-molecules and even the physical origin of van der Waals radius of atom in van der Waals equation of state.

2. The observation that the binding energy of dark color bond for $n = 2^{11} = 1/v_0$ of the scaling of $\hbar$ corresponds to the bond energy.5 eV of hydrogen bond raises the fascinating possibility that hydrogen bonds is accompanied by a color bond between proton and oxygen nucleus. Also more general chemical bonds might be accompanied by color bonds so that dark color physics might be an essential part of molecular physics. Color bonds might be also responsible for the formation of liquid phase and thus solid state. Dark weak bonds between nuclei could be involved and might be responsible for the repulsive core of van der Waals force and be part of molecular physics too. There is evidence for two kinds of hydrogen bonds [D51] : a possible identification is in terms of p-adic scaling of hydrogen bonds by a factor 2. This kind of doubling is predicted by nuclear string model [L3], [L3].

3. Years after writing this piece of text emerged the idea that covalent bonds of biopolymers might be accompanied by color bonds carrying the metabolic energy liberated in the decay of these polymers [K50]. Polymer like sequences of "half-dark" water molecules with one dark proton with dark protons connected by color bonds to form dark nucleus could have emerged as prebiotic counterparts of biomolecules and carry metabolic energy in color bonds and realize genetic code [K44, L3]. They could accompany ordinary bio-bolymers in water environment and color bonds could carry the metabolic energy. There are of course many other options, and one must have open mind since the belief that biochemistry is understood reduces to high extent to the belief in the reductionistic dogma.

4. Tetrahedral water clusters consisting of 14 water molecules would contain 8 dark protons which corresponds to a magic number for a dark nucleus consisting of protons. Icosahedral water clusters in turn consist of 20 tetrahedral clusters. This raises the question whether fractally scaled up super-nuclei could be in question. If one accepts the vision about dark matter hierarchy based in Jones inclusions to be discussed briefly later, tetrahedral and icosahedral structures of water could correspond directly to the unique genuinely 3-dimensional $G_a = E_6$ and E_8 coverings of CP_2 with $n_a = 3$ and $n_a = 5$ assignable to dark electrons. Icosahedral structures are also very abundant in living matter, mention only viruses.

Other anomalies

There are also other anomalies which might relate to the hierarchy of Planck constants and also to dark weak forces.

1. Exotic chemistries

Exotic chemistries [D55] in which clusters of atoms of given given type mimic the chemistry of another element. These systems behave as if nuclei would form a jellium (constant charge density) defining a harmonic oscillator potential for electrons. Magic numbers correspond to full electron shells analogous to noble gas elements. It is difficult to understand why the constant charge density approximation works so well. If nuclear protons are in large $\hbar(M^4)$ phase with Fermat integer $n_F = 3 \times 2^{11}$, the electromagnetic sizes of nuclei would be about 2.4 Angstroms and the approximation would be natural.

As a matter, fact nuclear string model predicts that the nuclei can have as many as $3A$ exotic charge states obtained by giving neutral color bond charge ± 1: this would give rise to quite different kind of alchemy [L3]. [L3] revealing itself in cold fusion.

2. Free energy anomalies

The anomalies reported by free energy researchers such as over unity energy production in devices involving repeated formation and dissociation of H_2 molecules based on the original discovery of Nobelist Irwing Langmuir [D42] (see for instance [H16]) suggest that part of H atoms might end up to dark matter phase liberating additional energy. The "mono-atomic" elements of Hudson suggest also dark nuclear physics [H9]. There is even evidence for macroscopic transitions to dark phase [H30, H17, H15].

3. Tritium beta decay anomaly and findings of Shnoll

Tritium beta decay anomaly [C11, C15, C18, C16] suggests exotic nuclear physics related to weak interactions. The evidence for the variation of the rates of nuclear and chemical processes correlating with astrophysical periods [E7] , [E7] could be understood in terms of weak fields created by dark matter and affect by astrophysical phenomena.

2.1.2 Dark Rules

I have done a considerable amount of trials and errors in order to identify the basic rules allowing to understand what it means to be dark matter is and what happens in the phase transition to dark matter. It is good to try to summarize the basic rules of p-adic and dark physics allowing to avoid obvious contradictions.

The notion of field body

The notion of "field body" implied by topological field quantization is essential. There would be em, $Z0$, W, gluonic, and gravitonic field bodies, each characterized by its one prime. The motivation for considering the possibility of separate field bodies seriously is that the notion of induced gauge field means that all induced gauge fields are expressible in terms of four CP_2 coordinates so that only single component of a gauge potential allows a representation as and independent field quantity. Perhaps also separate magnetic and electric field bodies for each interaction and identifiable as flux quanta must be considered. This kind of separation requires that the fermionic content of the flux quantum (say fermion and anti-fermion at the ends of color flux tube) is such that it conforms with the quantum numbers of the corresponding boson.

What is interesting that the conceptual separation of interactions to various types would have a direct correlate at the level of space-time topology. From a different perspective inspired by the general vision that many-sheeted space-time provides symbolic representations of quantum physics, the very fact that we make this conceptual separation of fundamental interactions could reflect the topological separation at space-time level.

The p-adic mass calculations for quarks encourage to think that the p-adic length scale characterizing the mass of particle is associated with its electromagnetic body and in the case of neutrinos with its Z^0 field body. Z^0 field body can contribute also to the mass of charged particles but the contribution would be small. It is also possible that these field bodies are purely magnetic for color and weak interactions. Color flux tubes would have exotic fermion and anti-fermion at their ends and define colored variants of pions. This would apply not only in the case of nuclear strings but also to molecules and larger structures so that scaled variants of elementary particles and standard model would appear in all length scales as indeed implied by the fact that classical electro-weak and color fields are unavoidable in TGD framework.

One can also go further and distinguish between magnetic field body of free particle for which flux quanta start and return to the particle and "relative field" bodies associated with pairs of particles. Very complex structures emerge and should be essential for the understanding the space-time correlates of various interactions. In a well-defined sense they would define space-time correlate for the conceptual analysis of the interactions into separate parts. In order to minimize confusion it should be emphasized that the notion of field body used in this chapter relates to those space-time correlates of interactions, which are more or less *static* and related to the formation of *bound states.*

What dark variant of elementary particle means

It is not at all clear what the notion of dark variant of elementary particle or of larger structures could mean.

1. Are only field bodies dark?

One variety of dark particle is obtained by making some of the field bodies dark by increasing the value of Planck constant. This hypothesis could be replaced with the stronger assumption that elementary particles are maximally quantum critical systems so that they are same irrespective of the value of the Planck constant. Elementary particles would be represented by partonic 2-surfaces, which belong to the universal orbifold singularities remaining invariant by all groups $G_a \times G_b$ for a given choice of quantization axes. If $G_a \times G_b$ is assumed to leave invariant the choice of the quantization axes, it must be of the form $Z_{n_a} \times Z_{n_b} \subset SO(3) \times SU(3)$. Partonic 2-surface would belong to $M^2 \times CP_2/U(1) \times U(1)$, where M^2 is spanned by the quantization axis of angular momentum and the time axis defining the rest system.

A different way to say this is that the CP_2 type extremal representing particle would suffer multiple topological condensation on its field bodies so that there would be no separate "particle space-time sheet".

Darkness would be restricted to particle interactions if it is assigned with topological field quanta mediating interactions. The value of the Planck constant would be assigned to a particular interaction between systems rather than system itself. This conforms with the original finding that gravitational Planck constant satisfies $\hbar_{gr} = GM_1M_2/v_0$, $v_0 \simeq 2^{-11}$. Since each interaction can give rise to a hierarchy dark phases, a rich variety of partially dark phases is predicted. The standard assumption that dark matter is visible only via gravitational interactions would mean that gravitational field body would not be dark for this particular dark matter. Note however that gravitational Planck constant h_{fr} having gigantic values could have different origin as Planck constant h_{eff} emerging from considerations related to biology: this is discussed in [K92].

Complex combinations of dark field bodies become possible and the dream is that one could understand various phases of matter in terms of these combinations. All phase transitions, including the familiar liquid-gas and solid-liquid phase transitions, could have a unified description in terms of dark phase transition for an appropriate field body. At mathematical level Jones inclusions would provide this description.

The book metaphor for the interactions at space-time level is very useful in this framework. Elementary particles correspond to ordinary value of Planck constant analogous to the ordinary sheets of a book and the field bodies mediating their interactions are the same space-time sheet or at dark sheets of the book.

2. Can also elementary particles be dark?

Also dark elementary particles themselves rather than only the flux quanta could correspond to dark space-time sheet defining multiple coverings of $H/G_a \times G_b$. This would mean giving up the maximal quantum criticality hypothesis in the case of elementary particles. These sheets would be exact copies of each other. If single sheet of the covering contains topologically condensed space-time sheet, also other sheets contain its exact copy.

The question is whether these copies of space-time sheet defining classical identical systems can carry different fermionic quantum numbers or only identical fermionic quantum numbers so that the dark particle would be exotic many-fermion system allowing an apparent violation of statistics (N fermions in the same state).

Even if one allows varying number of fermions in the same state with respect to a basic copy of sheet, one ends up with the notion of N-atom in which nuclei would be ordinary but electrons would reside at the sheets of the covering. The question is whether symbolic representations essential for understanding of living matter could emerge already at molecular level via the formation of N-atoms.

Criterion for the transition to dark phase

The criterion $\alpha Q_1 Q_2 > 1$ for the transition to dark matter phase relates always to the interaction between two systems and the interpretation is that when the field strength characterizing the interaction becomes too strong, the interaction is mediated by dark space-time sheets which define $n = n(G_a) \times n(G_b)$-fold covering of $M^4 \times CP_2/G_a \times G_b$. The sharing of flux between different space-time sheets reduces the field strength associated with single sheet below the critical value.

Mersenne hypothesis

The generalization of the embedding space means a book like structure for which the pages are products of singular coverings or factor spaces of CD (causal diamond defined as intersection of future and past directed light-cones) and of CP_2 [K40]. This predicts that Planck constants are rationals and that given value of Planck constant corresponds to an infinite number of different pages of the Big Book, which might be seen as a drawback. If only singular covering spaces are allowed the values of Planck constant are products of integers and given value of Planck constant corresponds to a finite number of pages given by the number of decompositions of the integer to two different integers.

TGD inspired quantum biology and number theoretical considerations suggest preferred values for $r = \hbar/\hbar_0$. For the most general option the values of $\hbar$ are products and ratios of two integers n_a and n_b. Ruler and compass integers defined by the products of distinct Fermat primes and power of two are number theoretically favored values for these integers because the phases $exp(i2\pi/n_i)$, $i \in \{a, b\}$, in this case are number theoretically very simple and should have emerged first in the number theoretical evolution via algebraic extensions of p-adics and of rationals. p-Adic length scale hypothesis favors powers of two as values of r.

One can however ask whether a more precise characterization of preferred Mersennes could exist and whether there could exists a stronger correlation between hierarchies of p-adic length scales and Planck constants. Mersenne primes $M_k = 2^k - 1$, $k \in \{89, 107, 127\}$, and Gaussian Mersennes $M_{G,k} = (1+i)k-1$, $k \in \{113, 151, 157, 163, 167, 239, 241..\}$ are expected to be physically highly interesting and up to $k = 127$ indeed correspond to elementary particles. The number theoretical miracle is that all the four scaled up electron Compton lengths with $k \in \{151, 157, 163, 167\}$ are in the biologically highly interesting range 10 nm-2.5 μm). The question has been whether these define scaled up copies of electro-weak and QCD type physics with ordinary value of $\hbar$. The proposal that this is the case and that these physics are in a well-defined sense induced by the dark scaled up variants of corresponding lower level physics leads to a prediction for the preferred values of $r = 2^{k_d}$, $k_d = k_i - k_j$.

What induction means is that dark variant of exotic nuclear physics induces exotic physics with ordinary value of Planck constant in the new scale in a resonant manner: dark gauge bosons transform to their ordinary variants with the same Compton length. This transformation is natural since in length scales below the Compton length the gauge bosons behave as massless and free particles. As a consequence, lighter variants of weak bosons emerge and QCD confinement scale becomes longer.

This proposal will be referred to as Mersenne hypothesis. It leads to strong predictions about EEG [K37] since it predicts a spectrum of preferred Josephson frequencies for a given value of membrane potential and also assigns to a given value of $\hbar$ a fixed size scale having interpretation as the size scale of the body part or magnetic body. Also a vision about evolution of life emerges. Mersenne hypothesis is especially interesting as far as new physics in condensed matter length scales is considered: this includes exotic scaled up variants of the ordinary nuclear physics and their dark variants. Even dark nucleons are possible and this gives justification for the model of dark nucleons predicting the counterparts of DNA, RNA, tRNA, and amino-acids as well as realization of vertebrate genetic code [K115].

These exotic nuclear physics with ordinary value of Planck constant could correspond to ground states that are almost vacuum extremals corresponding to homologically trivial geodesic sphere of CP_2 near criticality to a phase transition changing Planck constant. Ordinary nuclear physics would correspond to homologically non-trivial geodesic sphere and far from vacuum extremal property. For vacuum extremals of this kind classical Z^0 field proportional to electromagnetic field is present and this modifies dramatically the view about cell membrane as Josephson junction. The model for cell membrane as almost vacuum extremal indeed led to a quantitative breakthrough in TGD inspired model of EEG and is therefore something to be taken seriously. The safest option concerning empirical facts is that the copies of electro-weak and color physics with ordinary value of Planck constant are possible only for almost vacuum extremals - that is at criticality against phase transition changing Planck constant.

2.1.3 Weak Form Of Electric Magnetic Duality, Screening Of Weak Charges, And Color Confinement?

TGD predicts the presence of long range classical weak fields and color fields and one should understand classically why quarks and leptons do not couple to these fields above weak boson length scale. Why the quarks inside ordinary nuclei do not generate long range weak fields and do not couple to them? Obviously the weak charges of quarks must be screened so that only electromagnetic charge remains. The extreme non-linearity of field equations in principle allows non-vanishing vacuum charge densities making possible this kind of screening. I have not been able to develop any detailed model for this.

A rather attractive looking explanation came with the discovery of electric-magnetic duality leading to a considerable progress in the understanding of basic quantum TGD. The basic implication of the duality is that Kähler electric charges of wormhole throats representing particles are proportional to Kähler magnetic charges so that the CP_2 projections of the wormhole throats are homologically non-trivial. The Kähler magnetic charges do not create long range monopole fields if they are neutralized by wormhole throats carrying opposite monopole charges and weak isospin neutralizing the axial isospin of the particle's wormhole throat. One could speak of confinement of weak isospin. The weak field bodies of elementary fermions would be replaced with string like objects with a length of order W boson Compton length. Electro-magnetic flux would be feeded to electromagnetic field body where it would be feeded to larger space-time sheets. Similar mechanism could apply in the case of color quantum numbers.

One of the basic questions closely related to the weak screening have been whether it is s possible to have a weak analog of the ordinary atom - say neutrino atom. Formally one can of course construct this kind of model and I have indeed doe this. The recent wiew about the screening of weak forces does not however allow neutrino atoms since the weak gauge fluxes flow along flux tubes and are screened by opposite charges at their end rather than being spherically symmetric Coulomb fields. Elementary particles themselves can be regarded as string like objects neutralized above weak boson Compton length. The size of the magnetic flux tubes however scales as $\sqrt{\hbar}$ so that large values of $\hbar$ it is in principle possible to zoom up the elementary particles and see what their interior looks like. This applies to both weak and color forces and might some day make possible study of elementary particles without gigantic accelerators.

2.1.4 Dark Weak Forces And Almost Vacuum Extremals

TGD suggests strongly the presence of long range weak force and the large parity breaking in living matter realized as chiral selection provides support for it. One would however like some more concrete quantitative evidence for the conjecture that the classical weak forces are indeed there. This kind of evidence comes from the model of cell membrane based on the hypothesis that cell membrane correspond to almost vacuum extremal.

1. Induced Kähler form vanishes for vacuum extremals. The condition for vanishing implies that classical Z^0 and electromagnetic fields are proportional to each other so that induced spinor field couples to both these fields. The assumption is that the quarks of nuclei and possibly also neutrinos correspond to a large value of Planck constant and therefore couple to the classical Z^0 field. Atomic electrons would not have these couplings. This modifies dramatically the model for the cell membrane as a Josephson junction and raises the scale of Josephson energies from IR range just above thermal threshold to visible and ultraviolet. The amazing finding is that the Josephson energies for biologically important ions correspond to the energies assigned to the peak frequencies in the biological activity spectrum of photoreceptors in retina suggesting. This suggests that almost vacuum extremals and thus also classical Z^0 fields could be in a central role in the understanding of the functioning of the cell membrane and of sensory qualia. This would also explain the large parity breaking effects in living matter.

   One can construct also a generalization of Josephson junction as transmembrane protein such that Josephson energy is generalized to include also the difference of cyclotron energies over the membrane. This allows to understand the role of protons in metabolism and large value about.5 eV of metabolic energy quantum roughtly 10 times larger that Josephson energy for cell membrane in terms of "square root of thermodynamics" replacing the ordinary thermodynamical model of cell membrane. In this case classical Z^0 force is not necessary. It is of course possible that cell membrane proteins can be in two phases: without or with classical Z^0 fields at string world sheets of dark fermions.

2. A further conjecture is that EEG and its predicted fractally scaled variants which same energies in visible and UV range but different scales of Josephson frequencies correspond to Josephson photons with various values of Planck constant. The decay of dark ELF photons with energies of visible photons would give rise to bunches of ordinary ELF photons. Bio-photons in turn could correspond to ordinary visible photons resulting in the phase transition of these photons to photons with ordinary value of Planck constant. This leads to a very detailed view about the role of dark electromagnetic radiation in biomatter and also to a model for how sensory qualia are realized [K41, K82, K37].

What darkness means in the case of nuclei is that the "weak" field bodies of quarks are dark so that the size scale assignable to them is of order cell size. This does not affect their electromagnetic field bodies so that it is possible to speak about ions in the ordinary sense of the word. If the size scale of a given part of field body corresponds to the Compton length proportional proportional to the p-adic length scale scaled up by $\sqrt{\hbar}$ then cell membrane thickness as a Compton scale for the field body of weak bosons means rather large value of $\hbar \sim 2^{151-89} = 2^{62}\hbar_0$. This would scale down 10^{14} Hz frequency of visible photons to about 10^{-4} Hz.

The appendix of the book gives a summary about basic concepts of TGD with illustrations. Pdf representation of same files serving as a kind of glossary can be found at `http://tgdtheory.fi/tgdglossary.pdf` [L13].

2.2 Weak Form Electric-Magnetic Duality And Its Implications

The notion of electric-magnetic duality [B3] was proposed first by Olive and Montonen and is central in $\mathcal{N}=4$ supersymmetric gauge theories. It states that magnetic monopoles and ordinary particles are two different phases of theory and that the description in terms of monopoles can be applied at the limit when the running gauge coupling constant becomes very large and perturbation theory fails to converge. The notion of electric-magnetic self-duality is more natural since for CP_2 geometry Kähler form is self-dual and Kähler magnetic monopoles are also Kähler electric monopoles and Kähler coupling strength is by quantum criticality renormalization group invariant rather than running coupling constant. The notion of electric-magnetic (self-)duality emerged already two decades ago in the attempts to formulate the Kähler geometric of world of classical worlds. Quite recently a considerable step of progress took place in the understanding of this notion [K30]. What seems to be essential is that one adopts a weaker form of the self-duality applying at partonic 2-surfaces. What this means will be discussed in the sequel.

Every new idea must be of course taken with a grain of salt but the good sign is that this concept leads to precise predictions. The point is that elementary particles do not generate monopole fields in macroscopic length scales: at least when one considers visible matter. The first question is whether elementary particles could have vanishing magnetic charges: this turns out to be impossible. The next question is how the screening of the magnetic charges could take place and leads to an identification of the physical particles as string like objects identified as pairs magnetic charged wormhole throats connected by magnetic flux tubes.

1. The first implication is a new view about electro-weak massivation reducing it to weak confinement in TGD framework. The second end of the string contains particle having electroweak isospin neutralizing that of elementary fermion and the size scale of the string is electro-weak scale would be in question. Hence the screening of electro-weak force takes place via weak confinement realized in terms of magnetic confinement.

2. This picture generalizes to the case of color confinement. Also quarks correspond to pairs of magnetic monopoles but the charges need not vanish now. Rather, valence quarks would be connected by flux tubes of length of order hadron size such that magnetic charges sum up to zero. For instance, for baryonic valence quarks these charges could be $(2,-1,-1)$ and could be proportional to color hyper charge.

3. The highly non-trivial prediction making more precise the earlier stringy vision is that elementary particles are string like objects: this could become manifest at LHC energies.

4. The weak form electric-magnetic duality together with Beltrami flow property of Kähler leads to the reduction of Kähler action to Chern-Simons action so that TGD reduces to almost topological QFT and that Kähler function is explicitly calculable. This has enormous impact concerning practical calculability of the theory.

5. One ends up also to a general solution ansatz for field equations from the condition that the theory reduces to almost topological QFT. The solution ansatz is inspired by the idea that all isometry currents are proportional to Kähler current which is integrable in the sense that the flow parameter associated with its flow lines defines a global coordinate. The proposed solution ansatz would describe a hydrodynamical flow with the property that isometry charges are conserved along the flow lines (Beltrami flow). A general ansatz satisfying the integrability conditions is found.

   The strongest form of the solution ansatz states that various classical and quantum currents flow along flow lines of the Beltrami flow defined by Kähler current (Kähler magnetic field associated with Chern-Simons action). Intuitively this picture is attractive. A more general ansatz would allow several Beltrami flows meaning multi-hydrodynamics. The integrability conditions boil down to two scalar functions: the first one satisfies massless d'Alembert equation in the induced metric and the gradients of the scalar functions are orthogonal. The interpretation in terms of momentum and polarization directions is natural.

2.2.1 Could A Weak Form Of Electric-Magnetic Duality Hold True?

Holography means that the initial data at the partonic 2-surfaces should fix the WCW metric. A weak form of this condition allows only the partonic 2-surfaces defined by the wormhole throats at which the signature of the induced metric changes. A stronger condition allows all partonic 2-surfaces in the slicing of space-time sheet to partonic 2-surfaces and string world sheets. Number theoretical vision suggests that hyper-quaternionicity *resp.* co-hyperquaternionicity constraint could be enough to fix the initial values of time derivatives of the embedding space coordinates in the space-time regions with Minkowskian *resp.* Euclidian signature of the induced metric. This is a condition on modified gamma matrices and hyper-quaternionicity states that they span a hyper-quaternionic sub-space.

Definition of the weak form of electric-magnetic duality

One can also consider alternative conditions possibly equivalent with this condition. The argument goes as follows.

1. The expression of the matrix elements of the metric and Kähler form of WCW in terms of the Kähler fluxes weighted by Hamiltonians of $\delta M^4_\pm$ at the partonic 2-surface X^2 looks very attractive. These expressions however carry no information about the 4-D tangent space of the partonic 2-surfaces so that the theory would reduce to a genuinely 2-dimensional theory, which cannot hold true. One would like to code to the WCW metric also information about the electric part of the induced Kähler form assignable to the complement of the tangent space of $X^2 \subset X^4$.

2. Electric-magnetic duality of the theory looks a highly attractive symmetry. The trivial manner to get electric magnetic duality at the level of the full theory would be via the identification of the flux Hamiltonians as sums of of the magnetic and electric fluxes. The presence of the induced metric is however troublesome since the presence of the induced metric means that the simple transformation properties of flux Hamiltonians under symplectic transformations -in particular color rotations- are lost.

3. A less trivial formulation of electric-magnetic duality would be as an initial condition which eliminates the induced metric from the electric flux. In the Euclidian version of 4-D YM theory this duality allows to solve field equations exactly in terms of instantons. This approach involves also quaternions. These arguments suggest that the duality in some form might work. The full electric magnetic duality is certainly too strong and implies that space-time surface at the partonic 2-surface corresponds to piece of CP_2 type vacuum extremal and can hold only in the deep interior of the region with Euclidian signature. In the region surrounding wormhole throat at both sides the condition must be replaced with a weaker condition.

4. To formulate a weaker form of the condition let us introduce coordinates (x^0, x^3, x^1, x^2) such (x^1, x^2) define coordinates for the partonic 2-surface and (x^0, x^3) define coordinates labeling partonic 2-surfaces in the slicing of the space-time surface by partonic 2-surfaces and string world sheets making sense in the regions of space-time sheet with Minkowskian signature. The assumption about the slicing allows to preserve general coordinate invariance. The weakest condition is that the generalized Kähler electric fluxes are apart from constant proportional to Kähler magnetic fluxes. This requires the condition

$$J^{03}\sqrt{g_4} = KJ_{12} \ . \tag{2.2.1}$$

A more general form of this duality is suggested by the considerations of [K46] reducing the hierarchy of Planck constants to basic quantum TGD and also reducing Kähler function for preferred extremals to Chern-Simons terms [B2] at the boundaries of CD and at light-like wormhole throats. This form is following

$$J^{n\beta}\sqrt{g_4} = K\epsilon \times \epsilon^{n\beta\gamma\delta}J_{\gamma\delta}\sqrt{g_4} \ . \tag{2.2.2}$$

Here the index n refers to a normal coordinate for the space-like 3-surface at either boundary of CD or for light-like wormhole throat. ϵ is a sign factor which is opposite for the two ends of CD. It could be also opposite of opposite at the opposite sides of the wormhole throat. Note that the dependence on induced metric disappears at the right hand side and this condition eliminates the potentials singularity due to the reduction of the rank of the induced metric at wormhole throat.

5. Information about the tangent space of the space-time surface can be coded to the WCW metric with loosing the nice transformation properties of the magnetic flux Hamiltonians if Kähler electric fluxes or sum of magnetic flux and electric flux satisfying this condition are used and K is symplectic invariant. Using the sum

$$J_e + J_m = (1+K)J_{12} \ , \tag{2.2.3}$$

where J denotes the Kähler magnetic flux, , makes it possible to have a non-trivial WCW metric even for $K = 0$, which could correspond to the ends of a cosmic string like solution carrying only Kähler magnetic fields. This condition suggests that it can depend only on Kähler magnetic flux and other symplectic invariants. Whether local symplectic coordinate invariants are possible at all is far from obvious, If the slicing itself is symplectic invariant then K could be a non-constant function of X^2 depending on string world sheet coordinates. The light-like radial coordinate of the light-cone boundary indeed defines a symplectically invariant slicing and this slicing could be shifted along the time axis defined by the tips of CD.

Electric-magnetic duality physically

What could the weak duality condition mean physically? For instance, what constraints are obtained if one assumes that the quantization of electro-weak charges reduces to this condition at classical level?

1. The first thing to notice is that the flux of J over the partonic 2-surface is analogous to magnetic flux

$$Q_m = \frac{e}{\hbar}\oint BdS = n \ .$$

n is non-vanishing only if the surface is homologically non-trivial and gives the homology charge of the partonic 2-surface.

2. The expressions of classical electromagnetic and Z^0 fields in terms of Kähler form [L2] , [L2] read as

$$\begin{aligned}\gamma &= \frac{eF_{em}}{\hbar} = 3J - sin^2(\theta_W)R_{03} \ , \\ Z^0 &= \frac{g_ZF_Z}{\hbar} = 2R_{03} \ .\end{aligned} \tag{2.2.4}$$

Here R_{03} is one of the components of the curvature tensor in vielbein representation and F_{em} and F_Z correspond to the standard field tensors. From this expression one can deduce

$$J = \frac{e}{3\hbar}F_{em} + sin^2(\theta_W)\frac{g_Z}{6\hbar}F_Z \ . \tag{2.2.5}$$

3. The weak duality condition when integrated over X^2 implies

$$\begin{aligned} \frac{e^2}{3\hbar}Q_{em} + \frac{g_Z^2 p}{6}Q_{Z,V} &= K\oint J = Kn \ , \\ Q_{Z,V} &= \frac{I_V^3}{2} - Q_{em} \ , \ p = sin^2(\theta_W) \ . \end{aligned} \tag{2.2.6}$$

   Here the vectorial part of the Z^0 charge rather than as full Z^0 charge $Q_Z = I_L^3 + sin^2(\theta_W)Q_{em}$ appears. The reason is that only the vectorial isospin is same for left and right handed components of fermion which are in general mixed for the massive states.

   The coefficients are dimensionless and expressible in terms of the gauge coupling strengths and using $\hbar = r\hbar_0$ one can write

$$\begin{aligned} \alpha_{em}Q_{em} &+ p\frac{\alpha_Z}{2}Q_{Z,V} = \frac{3}{4\pi} \times rnK \ , \\ \alpha_{em} &= \frac{e^2}{4\pi\hbar_0} \ , \ \alpha_Z = \frac{g_Z^2}{4\pi\hbar_0} = \frac{\alpha_{em}}{p(1-p)} \ . \end{aligned} \tag{2.2.7}$$

4. There is a great temptation to assume that the values of Q_{em} and Q_Z correspond to their quantized values and therefore depend on the quantum state assigned to the partonic 2-surface. The linear coupling of the Kähler-Dirac operator to conserved charges implies correlation between the geometry of space-time sheet and quantum numbers assigned to the partonic 2-surface. The assumption of standard quantized values for Q_{em} and Q_Z would be also seen as the identification of the fine structure constants α_{em} and α_Z. This however requires weak isospin invariance.

The value of K from classical quantization of Kähler electric charge

The value of K can be deduced by requiring classical quantization of Kähler electric charge.

1. The condition that the flux of $F^{03} = (\hbar/g_K)J^{03}$ defining the counterpart of Kähler electric field equals to the Kähler charge g_K would give the condition $K = g_K^2/\hbar$, where g_K is Kähler coupling constant which should invariant under coupling constant evolution by quantum criticality. Within experimental uncertainties one has $\alpha_K = g_K^2/4\pi\hbar_0 = \alpha_{em} \simeq 1/137$, where α_{em} is finite structure constant in electron length scale and $\hbar_0$ is the standard value of Planck constant.

2. The quantization of Planck constants makes the condition highly non-trivial. The most general quantization of r is as rationals but there are good arguments favoring the quantization as integers corresponding to the allowance of only singular coverings of CD andn CP_2. The point is that in this case a given value of Planck constant corresponds to a finite number pages of the "Big Book". The quantization of the Planck constant implies a further quantization of K and would suggest that K scales as $1/r$ unless the spectrum of values of Q_{em} and Q_Z allowed by the quantization condition scales as r. This is quite possible and the interpretation would be that each of the r sheets of the covering carries (possibly same) elementary charge. Kind of discrete variant of a full Fermi sphere would be in question. The interpretation in terms of anyonic phases [K75] supports this interpretation.

3. The identification of J as a counterpart of $eB/\hbar$ means that Kähler action and thus also Kähler function is proportional to $1/\alpha_K$ and therefore to $\hbar$. This implies that for large values of $\hbar$ Kähler coupling strength $g_K^2/4\pi$ becomes very small and large fluctuations are suppressed in the functional integral. The basic motivation for introducing the hierarchy of Planck constants was indeed that the scaling $\alpha \rightarrow \alpha/r$ allows to achieve the convergence of perturbation theory: Nature itself would solve the problems of the theoretician. This of course does not mean that the physical states would remain as such and the replacement of single particles with anyonic states in order to satisfy the condition for K would realize this concretely.

4. The condition $K = g_K^2/\hbar$ implies that the Kähler magnetic charge is always accompanied by Kähler electric charge. A more general condition would read as

$$K = n \times \frac{g_K^2}{\hbar}, n \in Z . \tag{2.2.8}$$

This would apply in the case of cosmic strings and would allow vanishing Kähler charge possible when the partonic 2-surface has opposite fermion and anti-fermion numbers (for both leptons and quarks) so that Kähler electric charge should vanish. For instance, for neutrinos the vanishing of electric charge strongly suggests $n = 0$ besides the condition that abelian Z^0 flux contributing to em charge vanishes.

It took a year to realize that this value of K is natural at the Minkowskian side of the wormhole throat. At the Euclidian side much more natural condition is

$$K = \frac{1}{hbar} . \tag{2.2.9}$$

In fact, the self-duality of CP_2 Kähler form favours this boundary condition at the Euclidian side of the wormhole throat. Also the fact that one cannot distinguish between electric and magnetic charges in Euclidian region since all charges are magnetic can be used to argue in favor of this form. The same constraint arises from the condition that the action for CP_2 type vacuum extremal has the value required by the argument leading to a prediction for gravitational constant in terms of the square of CP_2 radius and α_K the effective replacement $g_K^2 \rightarrow 1$ would spoil the argument.

The boundary condition $J_E = J_B$ for the electric and magnetic parts of Kählwer form at the Euclidian side of the wormhole throat inspires the question whether all Euclidian regions could be self-dual so that the density of Kähler action would be just the instanton density. Self-duality follows if the deformation of the metric induced by the deformation of the canonically imbedded CP_2 is such that in CP_2 coordinates for the Euclidian region the tensor $(g^{\alpha\beta}g^{\mu\nu} - g^{\alpha\nu}g^{\mu\beta})/\sqrt{g}$ remains invariant. This is certainly the case for CP_2 type vacuum extremals since by the light-likeness of M^4 projection the metric remains invariant. Also conformal scalings of the induced metric would satisfy this condition. Conformal scaling is not consistent with the degeneracy of the 4-metric at the wormhole.

Reduction of the quantization of Kähler electric charge to that of electromagnetic charge

The best manner to learn more is to challenge the form of the weak electric-magnetic duality based on the induced Kähler form.

1. Physically it would seem more sensible to pose the duality on electromagnetic charge rather than Kähler charge. This would replace induced Kähler form with electromagnetic field, which is a linear combination of induced Kahler field and classical Z^0 field

$$\begin{aligned} \gamma &= 3J - sin^2\theta_W R_{12} , \\ Z^0 &= 2R_{03} . \end{aligned} \tag{2.2.10}$$

Here $Z_0 = 2R_{03}$ is the appropriate component of CP_2 curvature form [L2]. For a vanishing Weinberg angle the condition reduces to that for Kähler form.

2. For the Euclidian space-time regions having interpretation as lines of generalized Feynman diagrams Weinberg angle should be non-vanishing. In Minkowskian regions Weinberg angle could however vanish. If so, the condition guaranteeing that electromagnetic charge of the partonic 2-surfaces equals to the above condition stating that the em charge assignable to the fermion content of the partonic 2-surfaces reduces to the classical Kähler electric flux at the Minkowskian side of the wormhole throat. One can argue that Weinberg angle must increase smoothly from a vanishing value at both sides of wormhole throat to its value in the deep interior of the Euclidian region.

3. The vanishing of the Weinberg angle in Minkowskian regions conforms with the physical intuition. Above elementary particle length scales one sees only the classical electric field reducing to the induced Kähler form and classical Z^0 fields and color gauge fields are effectively absent. Only in phases with a large value of Planck constant classical Z^0 field and other classical weak fields and color gauge field could make themselves visible. Cell membrane could be one such system [K82]. This conforms with the general picture about color confinement and weak massivation.

The GRT limit of TGD suggests a further reason for why Weinberg angle should vanish in Minkowskian regions.

1. The value of the Kähler coupling strength mut be very near to the value of the fine structure constant in electron length scale and these constants can be assumed to be equal.

2. GRT limit of TGD with space-time surfaces replaced with abstract 4-geometries would naturally correspond to Einstein-Maxwell theory with cosmological constant which is non-vanishing only in Euclidian regions of space-time so that both Reissner-Nordström metric and CP_2 are allowed as simplest possible solutions of field equations [K114]. The extremely small value of the observed cosmological constant needed in GRT type cosmology could be equal to the large cosmological constant associated with CP_2 metric multiplied with the 3-volume fraction of Euclidian regions.

3. Also at GRT limit quantum theory would reduce to almost topological QFT since Einstein-Maxwell action reduces to 3-D term by field equations implying the vanishing of the Maxwell current and of the curvature scalar in Minkowskian regions and curvature scalar + cosmological constant term in Euclidian regions. The weak form of electric-magnetic duality would guarantee also now the preferred extremal property and prevent the reduction to a mere topological QFT.

4. GRT limit would make sense only for a vanishing Weinberg angle in Minkowskian regions. A non-vanishing Weinberg angle would make sense in the deep interior of the Euclidian regions where the approximation as a small deformation of CP_2 makes sense.

The weak form of electric-magnetic duality has surprisingly strong implications for the basic view about quantum TGD as following considerations show.

2.2.2 Magnetic Confinement, The Short Range Of Weak Forces, And Color Confinement

The weak form of electric-magnetic duality has surprisingly strong implications if one combines it with some very general empirical facts such as the non-existence of magnetic monopole fields in macroscopic length scales.

How can one avoid macroscopic magnetic monopole fields?

Monopole fields are experimentally absent in length scales above order weak boson length scale and one should have a mechanism neutralizing the monopole charge. How electroweak interactions become short ranged in TGD framework is still a poorly understood problem. What suggests itself is the neutralization of the weak isospin above the intermediate gauge boson Compton length by neutral Higgs bosons. Could the two neutralization mechanisms be combined to single one?

1. In the case of fermions and their super partners the opposite magnetic monopole would be a wormhole throat. If the magnetically charged wormhole contact is electromagnetically neutral but has vectorial weak isospin neutralizing the weak vectorial isospin of the fermion only the electromagnetic charge of the fermion is visible on longer length scales. The distance of this wormhole throat from the fermionic one should be of the order weak boson Compton length. An interpretation as a bound state of fermion and a wormhole throat state with the quantum numbers of a neutral Higgs boson would therefore make sense. The neutralizing throat would have quantum numbers of $X_{-1/2} = \nu_L\overline{\nu}_R$ or $X_{1/2} = \overline{\nu}_L\nu_R$. $\nu_L\overline{\nu}_R$ would not be neutral Higgs boson (which should correspond to a wormhole contact) but a super-partner of left-handed neutrino obtained by adding a right handed neutrino. This mechanism would apply separately to the fermionic and anti-fermionic throats of the gauge bosons and corresponding space-time sheets and leave only electromagnetic interaction as a long ranged interaction.

2. One can of course wonder what is the situation situation for the bosonic wormhole throats feeding gauge fluxes between space-time sheets. It would seem that these wormhole throats must always appear as pairs such that for the second member of the pair monopole charges and I_V^3 cancel each other at both space-time sheets involved so that one obtains at both space-time sheets magnetic dipoles of size of weak boson Compton length. The proposed magnetic character of fundamental particles should become visible at TeV energies so that LHC might have surprises in store!

Well-definedness of electromagnetic charge implies stringiness

Well-definedness of electromagnetic charged at string world sheets carrying spinor modes is very natural constraint and not trivially satisfied because classical W boson fields are present. As a matter fact, all weak fields should be effectively absent above weak scale. How this is possible classical weak fields identified as induced gauge fields are certainly present.

The condition that em charge is well defined for spinor modes implies that the space-time region in which spinor mode is non-vanishing has 2-D CP_2 projection such that the induced W boson fields are vanishing. The vanishing of classical Z^0 field can be poses as additional condition - at least in scales above weak scale. In the generic case this requires that the spinor mode is restricted to 2-D surface: string world sheet or possibly also partonic 2-surface. This implies that TGD reduces to string model in fermionic sector. Even for preferred extremals with 2-D projecting the modes are expected to allow restriction to 2-surfaces. This localization is possible only for Kähler-Dirac action.

A word of warning is however in order. The GRT limit or rather limit of TGD as Einstein Yang-Mills theory replaces the sheets of many-sheeted space-time with Minkowski space with effective metric obtained by summing to Minkowski metric the deviations of the induced metrics of space-time sheets from Minkowski metric. For gauge potentials a similar identification applies. YM-Einstein equations coupled with matter and with non-vanishing cosmological constant are expected on basis of Poincare invariance. One cannot exclude the possibility that the sums of weak gauge potentials from different space-time sheet tend to vanish above weak scale and that well-definedness of em charge at classical level follows from the effective absence of classical weak gauge fields.

Magnetic confinement and color confinement

Magnetic confinement generalizes also to the case of color interactions. One can consider also the situation in which the magnetic charges of quarks (more generally, of color excited leptons and quarks) do not vanish and they form color and magnetic singles in the hadronic length scale. This would mean that magnetic charges of the state $q_{\pm 1/2} - X_{\mp 1/2}$ representing the physical quark would not vanish and magnetic confinement would accompany also color confinement. This would explain why free quarks are not observed. To how degree then quark confinement corresponds to magnetic confinement is an interesting question.

For quark and antiquark of meson the magnetic charges of quark and antiquark would be opposite and meson would correspond to a Kähler magnetic flux so that a stringy view about meson emerges. For valence quarks of baryon the vanishing of the net magnetic charge takes place provided that the magnetic net charges are $(\pm 2, \mp 1, \mp 1)$. This brings in mind the spectrum of color hyper charges coming as $(\pm 2, \mp 1, \mp 1)/3$ and one can indeed ask whether color hypercharge correlates with the Kähler magnetic charge. The geometric picture would be three strings connected to single vertex. Amusingly, the idea that color hypercharge could be proportional to color hyper charge popped up during the first year of TGD when I had not yet discovered CP_2 and believed on $M^4 \times S^2$.

p-Adic length scale hypothesis and hierarchy of Planck constants defining a hierarchy of dark variants of particles suggest the existence of scaled up copies of QCD type physics and weak physics. For p-adically scaled up variants the mass scales would be scaled by a power of $\sqrt{2}$ in the most general case. The dark variants of the particle would have the same mass as the original one. In particular, Mersenne primes $M_k = 2^k - 1$ and Gaussian Mersennes $M_{G,k} = (1+i)^k - 1$ has been proposed to define zoomed copies of these physics. At the level of magnetic confinement this would mean hierarchy of length scales for the magnetic confinement.

One particular proposal is that the Mersenne prime M_{89} should define a scaled up variant of the ordinary hadron physics with mass scaled up roughly by a factor $2^{(107-89)/2} = 512$. The size scale of color confinement for this physics would be same as the weal length scale. It would look more natural that the weak confinement for the quarks of M_{89} physics takes place in some shorter scale and M_{61} is the first Mersenne prime to be considered. The mass scale of M_{61} weak bosons would be by a factor $2^{(89-61)/2} = 2^{14}$ higher and about 1.6×10^4 TeV. M_{89} quarks would have virtually no weak interactions but would possess color interactions with weak confinement length scale reflecting themselves as new kind of jets at collisions above TeV energies.

In the biologically especially important length scale range 10 nm -2500 nm there are as many as four scaled up electron Compton lengths $L_e(k) = \sqrt{5}L(k)$: they are associated with Gaussian Mersennes $M_{G,k}$, $k = 151, 157, 163, 167$. This would suggest that the existence of scaled up scales of magnetic-, weak- and color confinement. An especially interesting possibly testable prediction is the existence of magnetic monopole pairs with the size scale in this range. There are recent claims about experimental evidence for magnetic monopole pairs [D33] .

Magnetic confinement and stringy picture in TGD sense

The connection between magnetic confinement and weak confinement is rather natural if one recalls that electric-magnetic duality in super-symmetric quantum field theories means that the descriptions in terms of particles and monopoles are in some sense dual descriptions. Fermions would be replaced by string like objects defined by the magnetic flux tubes and bosons as pairs of wormhole contacts would correspond to pairs of the flux tubes. Therefore the sharp distinction between gravitons and physical particles would disappear.

The reason why gravitons are necessarily stringy objects formed by a pair of wormhole contacts is that one cannot construct spin two objects using only single fermion states at wormhole throats. Of course, also super partners of these states with higher spin obtained by adding fermions and anti-fermions at the wormhole throat but these do not give rise to graviton like states [**?**] . The upper and lower wormhole throat pairs would be quantum superpositions of fermion anti-fermion pairs with sum over all fermions. The reason is that otherwise one cannot realize graviton emission in terms of joining of the ends of light-like 3-surfaces together. Also now magnetic monopole charges are necessary but now there is no need to assign the entities $X_\pm$ with gravitons.

Graviton string is characterized by some p-adic length scale and one can argue that below this length scale the charges of the fermions become visible. Mersenne hypothesis suggests that some Mersenne prime is in question. One proposal is that gravitonic size scale is given by electronic Mersenne prime M_{127}. It is however difficult to test whether graviton has a structure visible below this length scale.

What happens to the generalized Feynman diagrams is an interesting question. It is not at all clear how closely they relate to ordinary Feynman diagrams. All depends on what one is ready to assume about what happens in the vertices. One could of course hope that zero energy ontology could allow some very simple description allowing perhaps to get rid of the problematic aspects of Feynman diagrams.

1. Consider first the recent view about generalized Feynman diagrams which relies ZEO. A highly attractive assumption is that the particles appearing at wormhole throats are on mass shell particles. For incoming and outgoing elementary bosons and their super partners they would be positive it resp. negative energy states with parallel on mass shell momenta. For virtual bosons they the wormhole throats would have opposite sign of energy and the sum of on mass shell states would give virtual net momenta. This would make possible twistor description of virtual particles allowing only massless particles (in 4-D sense usually and in 8-D sense in TGD framework). The notion of virtual fermion makes sense only if one assumes in the interaction region a topological condensation creating another wormhole throat having no fermionic quantum numbers.

2. The addition of the particles $X^{\pm}$ replaces generalized Feynman diagrams with the analogs of stringy diagrams with lines replaced by pairs of lines corresponding to fermion and $X_{\pm 1/2}$. The members of these pairs would correspond to 3-D light-like surfaces glued together at the vertices of generalized Feynman diagrams. The analog of 3-vertex would not be splitting of the string to form shorter strings but the replication of the entire string to form two strings with same length or fusion of two strings to single string along all their points rather than along ends to form a longer string. It is not clear whether the duality symmetry of stringy diagrams can hold true for the TGD variants of stringy diagrams.

3. How should one describe the bound state formed by the fermion and $X^{\pm}$? Should one describe the state as superposition of non-parallel on mass shell states so that the composite state would be automatically massive? The description as superposition of on mass shell states does not conform with the idea that bound state formation requires binding energy. In TGD framework the notion of negentropic entanglement has been suggested to make possible the analogs of bound states consisting of on mass shell states so that the binding energy is zero [K59] . If this kind of states are in question the description of virtual states in terms of on mass shell states is not lost. Of course, one cannot exclude the possibility that there is infinite number of this kind of states serving as analogs for the excitations of string like object.

4. What happens to the states formed by fermions and $X_{\pm 1/2}$ in the internal lines of the Feynman diagram? Twistor philosophy suggests that only the higher on mass shell excitations are possible. If this picture is correct, the situation would not change in an essential manner from the earlier one.

The highly non-trivial prediction of the magnetic confinement is that elementary particles should have stringy character in electro-weak length scales and could behaving to become manifest at LHC energies. This adds one further item to the list of non-trivial predictions of TGD about physics at LHC energies [K60] .

2.3 Dark Matter Hierarchy, Genetic Machinery, And The Un-Reasonable Selectivity Of Bio-Catalysis

One of the most fascinating outcomes of ideas related to the dark matter hierarchy is the notion of inherently dark fractional atom (molecule) generalizing the notion of Bose-Einstein condensate to the fermionic case. These notions might provide an elegant manner to understand the mysteries of DNA replication, transcription, and translation, and more generally, the incredible selectivity of bio-catalysis.

As often, the original idea was not quite correct. I spoke about N-atoms rather than fractional atoms. In particular, the mass of N-molecule was N times larger than that of the ordinary molecule apart from corrections from binding energy. The more precise view about dark matter hierarchy led to the realization that fractionization of all quantum numbers occurs. In the most general case one can have fractional particles with particle number $n = k/r$, $k = 1, .., r$, $r = \frac{\hbar}{\hbar_0}$. This leaves the model essentially as such at formal level. The model is however much more realistic than the original one since fractional atoms have mass which is never larger than that of ordinary atom and also conforms with the recent view about the origin of the hierarchy of Planck constants.

2.3.1 Dark Atoms And Dark Cyclotron States

The development of the notion of dark atom involves many side tracks which make me blush. The first naïve guess was that dark atom would be obtained by simply replacing Planck constant with its scaled counterpart in the basic formulas and interpreting the results geometrically. After some obligatory twists and turns it became clear that this assumption is indeed the most plausible one. The main source of confusion has been the lack of precise view about what the hierarchy of Planck constants means at the level of embedding space at space-time.

The rules are very simple when one takes the singular coverings assigned to the many-valuedness of the time-derivatives of embedding space coordinates as functions of canonical momentum densities as a starting point.

1. The mass and charge of electron are fractionized as is also the reduced mass in Schrödinger equation. This implies the replacements $e \rightarrow e/r$, $m \rightarrow m/r$, and $\hbar \rightarrow r\hbar_0$, $r = n_a n_b$, in the general formula for the binding energy assigned with single sheet of the covering. If maximal number $n_a n_b$ are present corresponding to a full "Fermi sphere", the total binding energy is r times the binding energy associated with single sheet.

2. In the case of hydrogen atom the proportionality $E \propto m/\hbar^2$ implies that the binding energy for single sheet of the covering scales as $E \rightarrow E/(n_a n_b)^3$ and maximal binding energy scales as $E \rightarrow E/(n_a n_b)^2$. This conforms with the naïve guess. For high values of the nuclear charge Z it can happen that the binding energy is larger than the rest mass and fractionization might take place when binding energy is above critical fraction of the rest mass.

3. In the case of cyclotron energies one must must decide what happens to the magnetic flux. Magnetic flux quantization states that the flux is proportional to $\hbar$ for each sheet separately. Hence one has $\Phi \rightarrow r\Phi$ for each sheet and the total flux scales as r^2. Since the dimensions of the flux quantum are scaled up by r the natural scaling of the size of flux quantum is by r^2. Therefore the quantization of the magnetic flux requires the scaling $B \rightarrow B/r$. The cyclotron energy for single sheet satisfies $E \propto \hbar qB/m$ and since both mass m and charge q become fractional, the energy E for single sheet remains invariant whereas total cyclotron energy is scaled up by r in accordance with the original guess and the assumption used in applications.

4. Dark cyclotron states are expected to be stable up to temperatures which are r times higher than for ordinary cyclotron states. The states of dark hydrogen atoms and its generalizations are expected to be stable at temperatures scaled down by $1/r^2$ in the first approximation.

5. Similar arguments allow to deduce the values of binding energies in the general case once the formula of the binding energy given by standard quantum theory is known.

The most general option option allows fractional atoms with proton and electron numbers varying from $1/r$ to 1. One can imagine also the possibility of fractional molecules. The analogs of chemical bonds between fractional hydrogen atoms with $N-k$ and k fractional electrons and protons can be considered and would give rise to a full shell of fractional electrons possessing an exceptional stability. These states would have proton and electron numbers equal to one.

Catalytic sites are one possible candidate for fractal electrons and catalyst activity might be perhaps understood as a strong tendency of fractal electron and its conjugate to fuse to form an ordinary electron.

Connection with quantum groups?

The phase $q = exp(i2\pi/r)$ brings unavoidably in mind the phases defining quantum groups and playing also a key role in the model of topological quantum computation [K6]. Quantum groups indeed emerge from the spinor structure in the "world of classical worlds" realized as the space of

3-surfaces in $M^4 \times CP_2$ and being closely related to von Neumann algebras known as hyper-finite factors of type II_1 [K118].

Only singular coverings are allowed if the hierarchy of Planck constants and corresponding hierarchy of singular coverings follows from the basic TGD. If the integer n characterizing the quantum phase allows identification with with $r = \hbar/\hbar_0$, living matter could be perhaps understood in terms of quantum deformations of the ordinary matter, which would be characterized by the quantum phases $q = exp(i2\pi/r)$. Hence quantum groups, which have for long time suspected to have significance in elementary particle physics, might relate to the mystery of living matter and predict an entire hierarchy of new forms of matter.

How to distinguish between fractional particles and ordinary particles?

The unavoidable question is whether bio-molecules in vivo could involve actually fractional atoms molecules as their building blocks. This raises a series of related questions.

1. Could it be that we can observe only the fusion of of dark fractional fold molecules to ordinary molecules or its reversal? Is the behavior of matter matter in vivo dictated by the dark matter commentn and of matter in vitro by ordinary matter? Could just the act of observing the matter in vivo in the sense of existing science make it ordinary dead matter?

2. If fractional atoms and molecules correspond to the maximum number of fractional quanta their masses are same as for ordinary atoms and molecules and only the different binding energy photon spectrum distinguishes between them. Situation changes all fractional states are possible and one obtains scaled down spectrum as a unique signature.

3. The fusion of fractional molecules to ordinary molecules in principle allows to conclude that fractional molecule was present. Could this process mean just the replacement of DNA in vivo with DNA in vitro?

2.3.2 Spontaneous Decay And Completion Of Dark Fractional Atoms As A Basic Mechanisms Of Bio-Chemistry?

The replication of DNA has remained for me a deep mystery and I dare to doubt that the reductionistic belief that this miraculous process is well-understood involves self deceptive elements. Of course the problem is much more general: DNA replication is only a single very representative example of the miracles of un-reasonable selectivity of the bio-catalysis. I take this fact as a justification for some free imagination inspired by the notion of dark fractional molecule.

Dark fermionic molecules can replicate via decay and spontaneous completion

Unit particle number for fractional atom or molecule means that the analog of closed electronic shell are in question so that the state is especially stable. Note that the analogy with full Fermi electronic sphere makes also sense. These atoms or molecules could decay to fractional atoms or molecules. with fractional particle numbers k/r and $(r-k)/r$.

Suppose that a fractional molecule with unit particle number decays into k/r-molecule and $(r-k)/r$-molecule. If r is even it is possible to have $k = r-k = r/2$ and the situation is especially symmetric. If fermionic $k/r < 1$ fractional atoms or molecules are present, one can imagine that they tend to be completed to full molecules spontaneously. Thus spontaneous decay and completion would favor the spontaneous replication (or rather fractionization) and dark molecules could be ideal replicators (fractionizators) The idea that the mechanisms of spontaneous decay and completion of dark fractional particles somehow lurk behind DNA replication and various high precision bio-catalytic processes is rather attractive.

Reduction of lock and key mechanism to spontaneous completion

DNA replication and molecular recognition by the lock and key mechanism are the two mysterious processes of molecular biology. As a matter fact, DNA replication reduces to spontaneous opening of DNA double strand and to the lock and key mechanism so that it could be enough to understand the opening of double strand in terms of spontaneous decay and lock and key mechanism in terms of spontaneous completion of fractional particle (-atom or -molecule).

Consider bio-molecules which fit like a lock and key. Suppose that they are accompanied by dark fractional atoms or molecules, to be called dark fractional particles in sequel, such that one has $k_1+k_2=r$ so that in the formation of bound state dark molecules combine to form r-molecule analogous to a full fermionic shell or full Fermi sea. This is expected to enhance the stability of this particular molecular complex and prefer it amongst generic combinations.

For instance, this mechanism would make it possible for nucleotide and its conjugate, DNA and mRNA molecule, and tRNA molecule and corresponding amino-acid to recognize each other. Spontaneous completion would allow to realize also the associations characterizing the genetic code as a map from RNAs to subset of RNAs and associations of this subset of RNAs with amino-acids (assuming that genetic code has evolved from RNA $\rightarrow$ RNA code as suggested in this chapter).

As such this mechanism allows a rather limited number of different lock and key combinations unless r is very large. There is however a simple generalization allowing to increase the representative power so that lock and key mechanism becomes analogous to a password used in computers. The molecule playing the role of lock *resp.* molecule would be characterized by a set of n fractional particles with $k_1 \in \{k_{1,1}, ...k_{1,n}\}$ *resp.* $k_2 \in \{k_{2,1} = r - k_{1,1}, ..., k_{2,n} = r - k_{1,n}\}$. The molecules with conjugate names would fit optimally together. Fractional molecules or fractional electrons or atoms appearing as their building blocks would be like letters of a text characterizing the name of the molecule.

The mechanism generalizes also to the case of $n > 2$ reacting molecules. The molecular complex would be defined by a partition of n copies of integer r to a sum of m integers $k_{k,i}$: $\sum_i k_{k,i} = r$.

This mechanism could provide a universal explanation for the miraculous selectivity of catalysts and this selectivity would have practically nothing to do with ordinary chemistry but would correspond to a new level of physics at which symbolic processes and representations based on dark fractional particles emerge.

Connection with the number theoretic model of genetic code?

The emergence of partitions of integers in the labelling of molecules by fractional particles suggests a connection with the number theoretical model of genetic code [K32], where DNA triplets are characterized by integers $n \in \{0, ..., 63\}$ and amino-acids by integers $0, 1$ and 18 primes $p < 64$. For instance, one can imagine that the integer n means that DNA triplet is labelled by n/r-particle. $r = 64$ would be the obvious candidate for r and conjugate DNA triplet would naturally have $n_c = 64 - n$.

The model relies on number-theoretic thermodynamics for the partitions of n to a sum of integers and genetic code is fixed by the minimization of number theoretic entropy which can be also negative and has thus interpretation as information. Perhaps these partitions could correspond to states resulting in some kind of decays of n-fermion to n_k/r-fermions with $\sum_{k=1}^{r} n_k = n$. The n_k/r-fermions should however not correspond to separate particles but something different. A possible interpretation is that partition corresponds to a state in which n_1/r particle is topologically condensed at $n_2/r \geq n_1/r$ particle topologically condensed....at $n_k/r \geq n_{k-1}/r$-particle. This would also automatically define a preferred ordering of the integers n_i in the partition.

An entire ensemble of labels would be present and depending on the situation codon could be labelled not only by n/r-particle but by any partition $n = \sum_{i=1}^{k} n_i$ corresponding to the state resulting in the decay of n/r-particle to k fractional particles.

Reduction of DNA replication to a spontaneous decay of r-particle

DNA replication could be induced by a spontaneous decay of r-particle inducing the instability of the double strand leading to a spontaneous completion of the component strands.

Strand and conjugate strand would be characterized by k_1/r-particle and $(r-k_1)/r$-particle, which combine to form r-particle as the double strand is formed. The opening of the double strand is induced by the decay of r-particle to k_1/r- and $(r-k_1)/r$-particles accompanying strand and its conjugate and after this both strands would complete themselves to double strands by the completion to r-particle.

It would be basically the stability of fractional particle which would make DNA double strand stable. Usually the formation of hydrogen bonds between strands and more generally, between the atoms of stable bio-molecule, is believed to explain the stability. Since the notion of hydrogen bond is somewhat phenomenological, one cannot exclude the possibility that these two mechanisms might be closely related to each other. I have already earlier considered the possibility that hydrogen bond might involve dark protons [K38]: this hypothesis was inspired by the finding that there seems to exist two kinds of hydrogen bonds [D51].

The reader has probably already noticed that the participating fractional molecules in the model of lock and key mechanism are like sexual partners, and if already molecules are conscious entities as TGD inspired theory of consciousness strongly suggests, one might perhaps see the formation of entangled bound states with positive number theoretic entanglement entropy accompanied by molecular experience of one-ness as molecular sex. Even more, the replication of DNA brings in also divorce and process of finding of new companions!

2.3.3 The New View About Hydrogen Bond And Water

Concretization of the above scenario leads to a new view about hydrogen bond and the role of water in bio-catalysis.

What the fractional particles labelling bio-molecules could be?

What the dark fractional particles defining the letters for the names of various bio-molecules could be? Dark fractional hydrogen atoms are the lightest candidates for the names of bio-molecules. The fusion could give rise to the hydrogen atom appearing in hydrogen bond. One could say the fractional hydrogen atoms belong to the molecules between which the hydrogen bond is formed. In absence of bond the fractional atoms would define active catalyst sites. This mechanism would also conform with the belief that hydrogen bonds guarantee the stability of bio-molecules.

This idea is not a mere speculation. The first experimental support for the notion of dark matter [K38] came from the experimental finding that water looks in atto-second time scale from the point of view of neutron diffraction and electron scattering chemically like $H_{1.5}O$: as if one fourth of protons are dark [D53, D50, D57, D32]. Dark protons would be identifiable as fractional protons. Of course, also dark hydrogen atoms can be considered.

One can imagine also a second option. The model for [I9] [K44] leads to a rather concrete view about how magnetic body controls biological body and receives sensory input from it. The model relies on the idea that dark water molecule clusters and perhaps also dark exotically ionized super-nuclei formed as linear closed strings of dark protons [K38] perform this mimicry. Dark proton super-nuclei are ideal for mimicking the cyclotron frequencies of ordinary atoms condensed to dark magnetic flux quanta. Of course, also partially ionized hydrogen fractional ions could perform the cyclotron mimicry of molecules with the same accuracy.

One can consider the possibility fractional molecules/atoms correspond to exotic atoms formed by electrons bound to exotically ionized dark super-nuclei: the sizes of these nuclei are however above atomic size scale so that dark electrons would move in a harmonic oscillator potential rather than Coulombic potential and form states analogous to atomic nuclei. The prediction would be the existence of magic electron numbers [K38]. Amazingly, there is strong experimental evidence for the existence of this kind of many-electron states. Even more, these states are able to mimic the chemistry of ordinary atoms [D55, D27, D20]. The formation of hydrogen bonds between catalyst and substrate could be the correlate for the fusion of fractional hydrogen atoms.

If the fusion process gives rise 1/1-hydrogen, its spontaneous decay to ordinary hydrogen would liberate the difference of binding energies as metabolic energy helping to overcome the energy barrier for the reaction. The liberated energy would be rather large and correspond 3.4 eV UV photon even for $r = 2$ which suggests that it does not relate with standard metabolism. For larger values of r the liberated energy rapidly approaches to the ground state energy of hydrogen. Note that the binding energy of ordinary hydrogen atom in state $n = r$ has in the lowest order approximation same energy as the ground state of dark hydrogen atom for $\hbar/\hbar_0 = r$ so that one can consider the possibility of a resonant coupling of these states.

Fractional protons and electrons have effective charge $\pm ke/r$ so that the binding regions of catalysts and reacting molecules could carry effective fractional surface charge.

This might relate in an interesting manner to the problem of how poly-electrolytes can be stable (I am grateful for Dale Trenary for pointing me the problem and for interesting discussions). For instance, DNA carries a charge of -2 units per nucleotide due to the phosphate backbone. The models trying to explain the stability involve effective binding of counter ions to the polyelectrolyte so that the resulting system has a lower charge density. The simulations of DNA condensation by Stevens [I80] however predict that counter ion charge should satisfy $z > 2$ in the case of DNA. The problem is of course that protons with $z = 1$ are the natural counter ions. The positive surface charge defined by the fractional protons attached to the nucleotides of DNA strand could explain the stability.

The hydrogen atoms in hydrogen bonds as fractional hydrogen atoms and $H_{1.5}O$ formula for water

The simplest assumption is that the hydrogens associated with hydrogen bonds are actually associated with 1/1 type dark hydrogen atoms. This hypothesis has interesting implications and could explain the formula $H_{1.5}O$ for water in atto-second time scales suggested by neutron diffraction and electron scattering [D53, D50, D57, D32].

The formation of hydrogen bond would correspond to a fusion of name and conjugate name between $H_{k/r}$-O-H atom and its conjugate $H_{(r-k)/r}$-O-H atom. The resulting pairs would obey the chemical formula H_3-O_2. Hence the formation of hydrogen bonds would predict the $H_{1.5}O$ formula suggested by neutron diffraction and electron scattering in atto-second time scale. This holds true only if one has complete pairing by hydrogen bonds. A more plausible explanation is that just the presence of fractioanl hydrogens implies the effect. Furthermore, the fraction of dark protons can depend on temperature.

The roles of water and ordered water in catalysis

The new view about hydrogen bond allows to understand the role of water in biology at qualitative level. For instance, one can

1. tentatively identify "ordered water" as a phase in which all $H_{k/r}$ atoms and their conjugates have combined to $H_{1/1}$ atoms,
2. understand why (or perhaps it is better to say "predict that") water containing $H_{k/r}$ atoms acts as a catalytic poison so that the binding sites of catalysts and reactants must be isolated from water unless the water is ordered,
3. justify the belief that gel phase involving ordered water is necessary for biological information processing,
4. understand why hydration causes hydrolysis,
5. understand the instability of DNA against decay to RNA outside nucleus.

A more more detailed sketch looks like following.

1. Suppose that at least part of water molecules appear in form $H_{k/r}$-OH and $H_{(r-k)/r}$-O-H. These molecules and the molecule $H_{1/1}$-OH_2 formed in their fusion has much smaller binding energy than ordinary water molecule and is expected to be unstable against transition to H_3O. This would suggest that the feed of metabolic energy is needed to generate the dark hydrogen atoms.

   Fractional dark water molecules can join pairwise to form H-O-($H_{1/1}$)-O-H$\equiv$ H_3O_2 with $H_{1/1}$-atoms replacing hydrogen in hydrogen bond. Also $H_{k_1/r}$-O-$H_{k_2/r}$ molecules are possible and could form closed strings obeying the chemical formula $O_n(H_{1/1})_n$. Also open strings with H-O: s at ends are possible. This phase of water might allow identificaton as "ordered water" believed to be associated with gel phase and be crucial for quantal information processing inside cell. Liquid crystal phase of water could correspond to a bundle of open vertical segments H-$O_n(H_{1/1})_{n-2}$-H forming a 2-dimensional liquid (vertical freezing).

2. Exotic water molecules could spoil the action of both catalyst and reactant molecules by attaching to the "letters" in the name of catalyst or reactant so that the letters are not visible and catalyst and reactant cannot recognize each other anymore. Hence binding sites of catalyst and reactant must be isolated from water containing fractional water molecules. This is what Sidorova and Rau [I101] suggest on basis of comparison of specific and non-specific catalysts: non-specific catalysts contain water in an isolated binding volume whereas for specific catalysts this volume is empty. An alternative mechanism hindering water molecules to attach to "letters" is that water is "ordered water" with no fractional water molecules present.

3. DNA is known to be stable against decay to RNA via hydration inside the cell but not outside. Hydration could correspond to the joining of fractional water to sites of DNA transforming it to RNA. Inside nucleus this cannot occur if water is in ordered water phase permanently.

How the first self-replicators emerged?

The identification of the first self replicator can be seen as perhaps the most fascinating and challenging problem faced by the pre-biotic model builders. Self replicator is by definition an entity which catalyzes its own replication. The analogy with the self-referential statement appearing in Gödel's theorem obvious.

In TGD framework self replication would reduce to a spontaneous decay of $H_{1/1}$-atom to $H_{k/r}$- and $H_{(r-k)/r}$-atoms and their subsequent completion to $H_{1/1}$-atoms

The picture about emergence of self-replicators would be roughly following.

1. The first self-replicating entities would have been plasmoids [I74] generating $H_{1/1}$ atoms whose presence would have made possible the emergence of the first molecular self replicators. The generation of $H_{1/1}$ atoms requires metabolic energy feed. In the first approximation the decay of $H_{1,1}$ to fractional hydrogen atoms does not liberate nor require energy.

2. $H_{k/r}$ atoms would have replaced some ordinary H-atoms in some negatively charged molecules M_i (perhaps MXTP, $X = A, U, C, G$) leading to a spontaneous emergence of linear negatively charged polymers consisting of M_i. One can imagine a coding in which each X corresponds to fixed value of k or collection of the (2 hydrogen bonds or 3 hydrogen bonds depending on X). This would make the attachment of X and its conjugate to form a hydrogen bond a highly favored process.

3. $H_{k/r}$ atoms would have taken also the role of active binding sites. In ordered water conjugate molecules $M_{c,i}$ having $H_{(r-k)/r}$ atoms as labels would have had high probability to attach to the polymers made of M_i.

4. RNA molecules are good candidates for self-replicators in the presence of ordered water. The phase transition from ordinary to ordered water (which would have developed later to sol-gel phase transition) would have been an essential element of replication.

The role of water in chiral selection

In the latest New Scientist (when I am writing this) there was a news telling that chiral selection occurs in water but not in heavy water [C17]. The L form of amino-acid glutamate is more stable than R in ordinary but not so in heavy water so that water environment must be responsible for the chirality selection of bio-molecules. The proposed explanation for the finding, whose importance cannot be over-estimated, was following.

1. Water molecules have two forms: orto- and para, depending on whether the nuclear spins of protons are parallel or opposite. Deuterium nuclei are spinless so that heavy water has only single form. In thermal equilibrium the fraction of orto water is 3/4 and para water 1/4.

2. Ortho-water is magnetic and if L form of amino-acid is slightly more magnetic than R, chirality selection can be understood as result of the magnetic interaction with water.

One can of course wonder how extremely short ranged weak interactions could produce strong enough effect on the magnetic moment. The situation is not made easier by the fact that magnetic interaction energies are inherently very weak and deep below the thermal threshold.

It is interesting to find whether these findings could be explained by and allow a more detailed formulation of the TGD based model for water based on the notion of fractional hydrogen atom, the new view about hydrogen bond, and the notion of dark protonic strings forming atomic sized super-nuclei carrying exotic weak charges.

1. Dark matter brings in long ranged exotic weak interactions which can produce large parity breaking effects in atomic and even longer length scales. The long ranged parity breaking weak interactions of the dark protonic super nuclei assignable to amino-acids and water could explain the chiral selection.

2. The magnetic interaction energy is scaled up by r, so that magnetic interactions could indeed play a key role. Ordinary classical magnetic fields are in TGD framework always accompanied by Z^0 magnetic fields. If amino-acids possess exotic em charge implying also exotic weak charge, one can understand the chiral breaking as being induced by the Z^0 magnetic interaction of aminocids with the dark magnetic fields generated by water molecules or their clusters possessing a net magnetic moment. In heavy water these fields would be absent so that the experimental findings could be understood.

3. The experimental evidence that water behaves as $H_{1.5}O$ in atto-second time scales means that 1/4: th of protons of water are effectively dark. The notion of fractional hydrogen atom leads to a model of hydrogen bond predicting correctly $H_{1.5}O$ formula and the dropping of 1/4: th of protons at larger possibly dark space-time sheets. The model also predicts that the mass of $H-O-H_r-O-H \equiv 2H_{1.5}O$ hydrogen bonded pairs is very near to the mass of 2 water molecules since there are $r \simeq m_p/m_e$ electrons involved. The paired molecules have three protons and non-vanishing net nuclear spin and thus generate a magnetic field and make hydrogen bonded water a magnetic system. The natural identification would be as dark magnetic field accompanied by Z^0 magnetic field responsible for the chiral selection.

   In the case of $D-O-D_r-O-D$ mass would be by about one proton mass m_p lower than mass of two D_2O molecules so that this D-bonded heavy water would look like $D_{1.25}O$ as far as masses are considered and $D_{1.5}O$ as far neutron diffraction and electron scattering are considered. In this case no magnetic field is generated since the nuclear spin of D vanishes and no chiral breaking results. This picture explains the experimental findings. The model is not equivalent with the proposal of the experimentalists.

4. The model predicts that the protons liberated in the formation of hydrogen bonds drop to larger space-time sheets but does not specify their fate. A strong constraint comes from the requirement that the dropped particles have exotic weak charges acting as sources of the geometrically unavoidable classical Z^0 magnetic field at dark space-time sheets causing the large parity breaking. This constraint is satisfied if the protons form super-nuclei (scaled up variants of nuclei) consisting of protonic strings connected by color bonds involving exotic quark and antiquark at its ends and some of these bonds are charged (of type $u\overline{d}$ or $d\overline{u}$: this could also generate the em charge needed to make the protonic string stable.

2.4 TGD Based Model For Qualia And Sensory Receptors

The identification of quantum number increments in quantum jump for a subsystem representing sub-self and the capacitor model of sensory receptor are already more than decade old ideas.

The concrete realization of this vision is based on several ideas that I have developed during last five years.

1. The vision about dark matter as a hierarchy of phases partially labeled by the value of Planck constant led to the model of DNA as topological quantum computer [K5]. In this model magnetic flux tubes connecting DNA nucleotides with the lipids of the cell membrane define strands of the braids defining topological quantum computations. The braid strand

corresponds to so called wormhole flux tube and has quark and antiquark at its ends. u and d quarks and their antiquarks code for four DNA nucleotides in this model.

2. Zero energy ontology assigns to elementary particles so called causal diamonds (CDs). For u and d quarks and electron these time scales are (6.5, .78, 100) ms respectively, and correspond to fundamental biorhythms. Electron time scale corresponds to 10 Hz fundamental biorhythm defining also the fundamental frequency of speech organs, .78 ms to kHz cortical synchrony [J37], and 160 Hz to cerebellar synchrony [J36]. Elementary particles therefore seem to be directly associated with neural activity, language, and presumably also hearing. One outcome was the modification of the earlier model of memetic code involving the notion of cognitive neutrino pair by replacing the sequence of cognitive neutrino pairs with that of quark sub-CDs within electron CD. Nerve pulses could induce the magnetization direction of quark coding for bit but there are also other possibilities. The detailed implications for the model of nerve pulse [K82] remain to be disentangled.

3. The understanding of the Negentropy Maximization Principle [K59] and the role of negentropic entanglement in living matter together with the vision about life as something in the intersection of real and p-adic worlds was a dramatic step forward. In particular, space-like and time-like negentropic entanglement (see **Fig.** `http://tgdtheory.fi/appfigures/cat.jpg` or **Fig. ??** in the appendix of this book) become basic aspects of conscious intelligence and are expected to be especially important for understanding the difference between speech and music.

4. One of the basic challenge has been to construct a quantitative model for cell membrane.

   (a) The first model was based on the assumption that long range weak forces however play a key role [K13]. They are made possible by the exotic ground state represented as almost vacuum extremal of Kähler action for which classical em and Z^0 fields are proportional to each other whereas for the standard ground state classical Z^0 fields are very weak. Neutrinos are present but it seems that they do not define cognitive or Boolean representations in the time scales characterizing neural activity. Electrons and quarks for which the time scales of causal diamonds correspond to fundamental biorhythms - one of the key observations during last years- take this role. The essential element is that the energies of the Josephson photons are in visible range. This would explain bio-photons and even why the frequencies assignable to visual receptors. The problem is that Weinberg angle must be assumed to be much smaller in the near vacuum extremal phase than in standard model.

   (b) Second model is based on Gerald Pollack's findings about fourth phase of water and exclusion zones [L15]. These zones inspire a model for pre-biotic cells. The outcome is a modification of the simplest model of Josephson junction. Besides resting potential also the difference between cyclotron energies between the two sides of the membrane plays a key role. This model allows to understand what happens in metabolism in terms of a quantum model replacing the thermodynamical model for cell membrane with its quantal "square root" inspired by Zero Energy Ontology. The model allows also to understand bio-photons as decay products of dark photons.

   (c) The success of the latter model does not of course mean that the weak forces could not be important in cell membrane scale and the realistic model could be a hybrid of these two models. The inclusion of Z^0 contribution to the effective magnetic field could also to the fact that the endogenous magnetic field deduced from Blackman's experiments is $B_{end} = 2B_E/5$ rather than B_E (Earth's magnetic field).

2.4.1 A General Model Of Qualia And Sensory Receptor

The identification of sensory qualia in terms of quantum number increments and geometric qualia representing geometric and kinematic information in terms of moduli of CD, the assignment of sensory qualia with the membrane of sensory receptor, and capacitor model of qualia are basic ideas behind the model. The communication of sensory data to magnetic body using Josephson photons is also a key aspect of the model.

A general model of qualia

It is good to start by summarizing the general vision about sensory qualia and geometric qualia in TGD Universe.

1. The basic assumption is that sensory qualia correspond to increments of various quantum numbers in quantum jump. Standard model quantum numbers- color quantum numbers, electromagnetic charge and weak isospin, and spin are the most obvious candidates. Also cyclotron transitions changing the integer characterizing cyclotron state could corresponds to some kind of quale- perhaps "a feeling of existence". This could make sense for the qualia of the magnetic body.

2. Geometric qualia could correspond to the increments of zero modes characterizing the induced CP_2 Käjhler form of the partonic 2-surface and of the moduli characterizing the causal diamonds serving as geometric correlates of selves. This moduli space involves the position of CD and the relative position of tips as well as position in CP_2 and relative position of two CP_2 points assigned to the future and past boundaries of CD. There are good motivations for proposing that the relative positions are quantized. This gives as a special case the quantization of the scale of CD in powers of two. Position and orientation sense could would represent this kind of qualia. Also kinematical qualia like sensation of acceleration could correspond to geometric qualia in generalized 4-D sense. For instance, the sensation about motion could be coded by Lorentz boots of sub-CD representing mental image about the object.

3. One can in principle distinguish between qualia assignable to the biological body (sensory receptors in particular) and magnetic body. The basic question is whether sensory qualia can be assigned only with the sensory receptors or with sensory pathways or with both. Geometric qualia might be assignable to the magnetic body and could provide third person perspective as a geometric and kinematical map of the body and its state of motion represented using the moduli space assignable to causal diamonds (CD). This map could be provided also by the body in which case the magnetic body would only share various mental images. The simplest starting assumption consistent with neuro-science is that sensory qualia are assigned with the cell membrane of sensory receptor and perhaps also with the neurons receiving data from it carried by Josephson radiation coding for the qualia and possibly partially regenerating them if the receiving neuron has same value of membrane potential as the sensory receptor when active. Note that during nerve pulse also this values of membrane potential is achieved for some time.

Could some sensory qualia correspond to the sensory qualia of the magnetic body?

Concerning the understanding of a detailed model for how sensory qualia are generated, the basic guideline comes from the notion of magnetic body and the idea that sensory data are communicated to the magnetic body as Josephson radiation associated with the cell membrane. This leaves two options: either the primary a sensory qualia are generated at the level of sensory receptor and the resulting mental images negentropically entangle with the "feeling of existence" type mental images at the magnetic body or they can be also generated at the level of the magnetic body by Josephson radiation -possibly as cyclotron transitions. The following arguments are to-be-or-not-to-be questions about whether the primary qualia must reside at the level of sensory receptors.

1. Cyclotron transitions for various cyclotron condensates of bosonic ions or Cooper pairs of fermionic ions or elementary particles are assigned with the motor actions of the magnetic body and Josephson frequencies with the communication of the sensory data. Therefore it would not be natural to assign qualia with cyclotron transitions. One the other hand, in zero energy ontology motor action can be regarded formally as a time reversed sensory perception, which suggests that cyclotron transitions correlated with the "feeling of existence" at magnetic body entangled with the sensory mental images. They could also code for the pitch of sound as will be found but this quale is strictly speaking also a geometric quale in the 4-D framework.

2. If Josephson radiation induces cyclotron transitions, the energy of Josephson radiation must correspond to that of cyclotron transition. This means very strong additional constraint not easy to satisfy except during nerve pulse when frequencies varying from about 10^{14} Hz down to kHz range are emitted the system remains Josephson contact. Cyclotron frequencies are also rather low in general, which requires that the value of $\hbar$ must be large in order to have cyclotron energy above the thermal threshold. This would however conform with the very beautiful dual interpretation of Josephson photons in terms of bio-photons and EEG. One expects that only high level qualia can correspond to a very large values of $\hbar$ needed.

   For the sake of completeness it should be noticed that one might do without large values of $\hbar$ if the carrier wave with frequency defined by the metabolic energy quantum assignable to the kicking and that the small modulation frequency corresponds to the cyclotron frequency. This would require that Josephson frequency corresponds to the frequency defined by the metabolic quantum. This is not consistent with the fact that very primitive organisms possess sensory systems.

3. If all primary qualia are assigned to the magnetic body, Josephson radiation must include also gluons and light counterparts of weak bosons are involved besides photons. This is quite a strong additional assumption and it will be found that the identification of sensory qualia in terms of quantum numbers of quark pair restricts them to the cell membrane. The coding of qualia by Josephson frequencies is however possible and makes it possible to regenerate them in nervous system. The successful model explaining the peak frequencies of photoreceptors in terms of ionic cyclotron frequencies supports this view and provides a realization for an old idea about spectroscopy of consciousness which I had already been ready to give up.

Capacitor model of sensory qualia

In capacitor model of sensory receptor the increments of quantum numbers are amplified as particles with given quantum numbers flow between the plates of capacitor like system and the second plate defines the sub-self responsible for the mental image. The generation of complementary qualia assignable to the two plates and bringing in mind complementary colors is predicted. The capacitor is at the verge of di-electric breakdown. The interior and exterior of the receptor cell are the most plausible candidates for the capacitor plates with lipid layers defining the analog of di-electric able to changes its properties. Josephson currents generating Josephson radiation could communicate the sensory percept to the magnetic body but would not generate genuine sensory qualia there (the pitch of sound would be interpreted as a geometric quale). The coding is possible if the basic qualia correspond in one-one manner to ionic Josephson currents. There are sensory receptors which themselves do not fire (this is the case for hair cells for hearing and tactile receptor cells) and in this case the neuron next to the receptor in the sensory pathway would take the role of the quantum critical system.

The notion of sensory capacitor can be generalized. In zero energy ontology the plates could be effectively replaced with positive and negative energy parts of zero energy state or with cyclotron Bose-Einstein condensates corresponding to two different energies. Plates could also correspond to a pair of space-time sheets labeled by different p-adic primes and the generation of quale would correspond in this case to a flow of particles between the space-time sheets or magnetic flux tubes connected by contacts defining Josephson junctions.

The TGD inspired model for photoreceptors [K82] relies crucially on the assumption that sensory neurons at least and probably all cell membranes correspond to nearly vacuum extremals with the value of Weinberg angle equal to $sin^2(\theta_W) = .0295$ and weak bosons having Compton length of order cell size and ordinary value of Planck constant. This also explains the large parity breaking effects in living matter. The almost vacuum extremal property conforms with the vision about cell membrane as a quantum critical system ideal for acting as a sensory receptor.

2.4.2 Detailed Model For The Qualia

The proposed vision about qualia requires a lot of new physics provided by TGD. What leads to a highly unique proposal is the intriguing coincidence of fundamental elementary particle time scales with basic time scales of biology and neuro science and the model of DNA as topological quantum computer [K5].

1. Zero energy ontology brings in the size scale of CD assignable to the field body of the elementary particle. Zero energy states with negentropic time-like entanglement between positive and negative energy parts of the state might provide a key piece of the puzzle. The negentropic entanglement (see **Fig.** `http://tgdtheory.fi/appfigures/cat.jpg` or **Fig. ??** in the appendix of this book) beween positive energy parts of the states associated with the sub-CD assignable to the cell membrane and sub-CD at the magnetic body is expected to be an important factor.

2. For the standard value of $\hbar$ the basic prediction would be 1 ms second time scale of d quark, 6.5 ms time scale of u quark, and.1 second time scale of electron as basic characterizes of sensory experience if one accept the most recent estimates $m(u) = 2$ MeV and $m(d) = 5$ MeV for the quark masses [C10]. These time scales correspond to 10 Hz, 160 Hz, and 1280 Hz frequencies, which all characterize neural activity (for the identification of 160 Hz frequency as cerebellar resonance frequency see [J36]). Hence quarks could be the most interesting particles as far as qualia are considered and the first working hypothesis would be that the fundamental quantum number increments correspond to those for quark-anti-quark pair. The identification in terms of quantum numbers of single quark is inconsistent with the model of color qualia.

3. The model of DNA as topological quantum computer led to the proposal that DNA nucleotides are connected to the lipids of the cell membrane by magnetic flux tubes having quark and antiquark at its ends such that the u and d quarks and their antiquarks code for the four nucleotides. The outer lipid layer was also assumed to be connected by flux tubes to the nucleotide in some other cell or in cell itself.

4. The model for DNA as topological quantum computer did not completely specify whether the flux tubes are ordinary flux tubes or wormhole flux tubes with possibly opposite signs of energy assigned with the members of the flux tube pair. Although it is not necessary, one could assume that the quantum numbers of the two parallel flux tubes cancel each other so that wormhole flux tube would be characterized by quantum numbers of quark pairs at its ends. It is not even necessary to assume that the net quantum numbers of the flux tubes vanish. Color confinement however suggests that the color quantum at the opposite ends of the flux tube are of opposite sign.

   (a) The absence of a flux tube between lipid layers was interpreted as an isolation from external world during the topological quantum computation. The emergence of the flux tube connection means halting of topological quantum computation. The flux tube connection with the external world corresponds to sensory perception at the level of DNA nucleotide in consistency with the idea that DNA plays the role of the brain of cell [K89]. The total color quantum numbers at the ends of the flux tubes were assumed to sum up to zero. This means that the fusion of the flux tubes ending to the interior and exterior cell membrane to single one creates a flux tube state not localized inside cell and that the interior of cell carries net quantum numbers. The attractive interpretation is that this process represents the generation of quale of single nucleotide.

   (b) The formation of the flux tube connection between lipid layers would involve the transformation of both quark-antiquark pairs to an intermediate state. There would be no kinematic constraints on the process nor to the mass scales of quarks. A possible mechanism for the separation of the two quark-antiquark pairs associated with the lipids from the system is double reconnection of flux tubes which leads to a situation in which the quark-antiquark pairs associated with the lipid layers are connected by short flux loops and separated to a disjoint state and there is a long wormhole flux tube connecting the nucleotides possibly belonging to different cells.

   (c) The state of two quark pairs need not have vanishing quantum numbers and one possibility is that the quantum numbers of this state code for qualia. If the total numbers of flux tubes are vanishing also the net quantum numbers of the resulting long flux tube connecting two different cells provide equivalent coding. A stronger condition is that this state has vanishing net quantum numbers and in this case the ends of the long flux tube would carry opposite quantum numbers. The end of flux tube at DNA nucleotide would characterize the quale.

5. Two identification of primary qualia are therefore possible.

   (a) If the flux tubes have vanishing net quantum numbers, the primary sensory quale can be assigned to single receptor cell and the flow of the quantum numbers corresponds to the extension of the system with vanishing net quantum numbers in two-cell system.

   (b) If the net quantum numbers of the flux tube need not vanish, the resulting two cell system carries non-vanishing quantum numbers as the pair of quark-antiquark pairs removes net quantum numbers out of the system.

6. If the net quantum numbers for the flux tubes vanish always, the specialization of the sensory receptor membrane to produce a specific quale would correspond to an assignment of specific quantum numbers at the DNA ends of the wormhole flux tubes attached to the lipid layers of the cell membrane. The simplest possibility that one can imagine is that the outer lipid layer is connected to the conjugate DNA nucleotide inside same cell nucleus. This option would however assign vanishing net quantum number increments to the cell as whole and is therefore unacceptable.

7. The formation of a temporary flux tube connection with another cell is necessary during the generation of quale and the question is what kind of cell is in question. The connection of the receptor to cells along the sensory pathway are expected to be present along the entire sensory pathway from DNA nucleotide to a nucleotide in the conjugate strand of second neuron to DNA nucleotide of the third neutron.... If Josephson photons are able to regenerate the quale in second neuron this would make it possible to replicate the quale along entire sensory pathway. The problem is that Josephson radiation has polarization orthogonal to axons and must propagate along the axon whereas the flux tube connection must be orthogonal to axon. Hence the temporary flux tube connection is most naturally between receptor cells and would mean horizontal integration of receptor cells to a larger structure. A holistic process in directions parallel and orthogonal to the sensory pathway would be in question. Of course, the flux tube could be also curved and connect the receptor to the next neuron along the sensory pathway.

8. The specialization of the neuron to sensory receptor would require in the framework of positive energy ontology that -as far as qualia assignable to the electro-weak quantum numbers are considered - all DNA nucleotides are identical by the corresponds of nucleotides with quarks and antiquarks. This cannot be the case. In zero energy ontology and for wormhole flux tubes it is however enough to assume that the net electroweak quantum numbers for the quark antiquark pairs assignable to the DNA wormhole contact are same for all nucleotides. This condition is easy to satisfy. It must be however emphasized that there is no reason to require that all nucleotides involved generate same quale and at the level of neurons sensory maps assigning different qualia to different nucleotides and lipids allowing DNA to sensorily perceive the external world are possible.

The model should be consistent with the assignment of the fundamental bio-rhythms with the CDs of electron and quarks.

1. Quark color should be free in long enough scales and cellular length scales are required at least. The QCD in question should therefore have long enough confinement length scales. The first possibility is provided by almost vacuum extremals with a long confinement scale also at the flux tubes. Large $\hbar$ for the cell membrane space-time sheet seems to be unavoidable and suggests that color is free in much longer length scale than cell length scale.

2. Since the length of the flux tubes connecting DNA and cell membrane is roughly 1 micrometer and by a factor of order 10^7 longer than the d quark Compton length, it seems that the value of Planck constant must be of this order for the flux tubes. This however scales up the time

scale of d quark CD by a factor of 10^{14} to about 10^4 years! The millisecond and 160 ms time scales are much more attractive. This forces to ask what happens to the quark-anti-quark pairs at the ends of the tubes.

3. The only possibility seems to be that the reconnection process involves a phase transition in which the closed flux tube structure containing the two quark pairs assignable to the wormhole contacts at lipid layers is formed and leaks to the page of the Big Book with pages partially labeled by the values of Planck constant. This page would correspond to the standard value of Planck constant so that the corresponding d quark CDs would have a duration of millisecond. The reconnection leading to the ordinary situation would take place after millisecond time scale. The standard physics interpretation would be as a quantum fluctuation having this duration. This sequence of quark sub-CDs could define what might be called memetic codon representation of the nerve pulse sequence.

4. One can also consider the possibility is that near vacuum extremals give rise to a copy of hadron physics for which the quarks associated with the flux tubes are light. The Gaussian Mersennes corresponding to $k = 151, 157, 163, 167$ define excellent p-adic time scales for quarks and light variants of weak gauge bosons. Quark mass 5 MeV would with $k = 120$ would be replaced with $k = 163$ (167) one would have mass 1.77 eV (.44 eV). Small scaling of both masses gives 2 eV and.5 eV which correspond to basic metabolic quanta in TGD framework. For quark mass of 2 MeV with $k = 123$ $k = 163$ (167) one would give masses.8 eV (.05 eV). The latter scale correspond to Josephson energy assignable with the membrane potential in the ordinary phase.

   In this case a phase transition transforming almost vacuum extremal to ordinary one takes place. What this would mean that the vacuum extremal property would hold true below much shorter p-adic length scale. In zero energy ontology the scaling up of quark masses is in principle possible. This option looks however too artificial.

2.4.3 Overall View About Qualia

This picture leads to the following overall view about qualia. There are two options depending on whether single quark-antiquark pair or two of them labels the qualia. In the following only the simpler option with single quark-antiquark pair is discussed.

1. All possible pairings of spin and electroweak isospin (or em charge) define 16 basic combinations if one assumes color singletness. If arbitrary color is allowed, there is a nine-fold increase of quantum numbers decomposable to color singlet and octet qualia and further into 3×15 qualia with vanishing increments of color quantum numbers and 6×16 qualia with non-vanishing increments of color quantum numbers. The qualia with vanishing increments for electroweak quantum numbers could correspond to visual colors. If electroweak quantum numbers of the quark-anti-quark pair vanish, one has 3×7 *resp.* 6×8 combinations of colorless *resp.* colored qualia.

2. There is a huge number of various combinations of these fundamental qualia if one assumes that each nucleotide defines its own quale and fundamental qualia would be analogous to constant functions and more general qualia to general functions having values in the space with $9 \times 16 - 1$ points. Only a very small fraction of all possible qualia could be realized in living matter unless the neurons in brain provide representations of body parts or of external world in terms of qualia assignable to lipid-nucleotide pairs. The passive DNA strand would be ideal in this respect.

3. The basic classification of qualia is as color qualia, electro-weak quale, and spin quale and products of these qualia. Also combinations of color qualiaandelectroweak and spin quale are possible and could define exotic sensory qualia perhaps not yet realized in the evolution. Synesthesia is usually explained in terms of sensory leakage between sensory pathways and this explanation makes sense also in TGD framework if there exists a feedback from the brain to the sensory organ. Synesthesia cannot however correspond to the product qualia: for "quantum synesthesia" cross association works in both directions and this distinguishes it from the ordinary synesthesia.

4. The idea about brain and genome as holograms encourages to ask whether neurons or equivalently DNA could correspond to sensory maps with individual lipids representing qualia combinations assignable to the points of the perceptive field. In this framework quantum synesthesia would correspond to the binding of qualia of single nucleotide (or lipid) of neuron cell membrane as a sensory representation of the external world. DNA is indeed a holographic representation of the body (gene expression of course restricts the representation to a part of organism). Perhaps it is this kind of representation also at the level of sensory experience so that all neurons could be little sensory copies of body parts as holographic quantum homunculi. In particular, in the associative areas of the cortex neurons would be quantum synesthetes experiencing the world in terms of composite qualia.

5. The number of flux tube connections generated by sensory input would code for the intensity of the quale. Josephson radiation would do the same at the level of communications to the magnetic body. Also the temporal pattern of the sequence of quale mental images matters. In the case of hearing this would code for the rhythmic aspects and pitch of the sound.

2.4.4 About Detailed Identification Of The Qualia

One can make also guesses about detailed correspondence between qualia and quantum number increments.

1. Visual colors would correspond to the increments of only color quantum numbers. Each biologically important ion would correspond to its own color increment in one-one correspondence with the three pairs of color-charged gluons and these would correspond to blue-yellow, red-green, and black white [K82]. Black-white vision would mean a restriction to the $SU(2)$ subgroup of color group. The model for the cell membrane as a nearly vacuum extremal assigns the peak frequencies corresponding to fundamental colors with biologically important ions. Josephson radiation could induce artificially the same color qualia in other neurons and this might provide an manner to communicate the qualia to the brain where they could be re-experienced at neuronal level. Some organisms are able to perceive also the polarization of light. This requires receptors sensitive to polarization. The spin of quark pair would naturally code for polarization quale.

2. Also tastes and odours define qualia with "colors". Certainly the increments of electroweak numbers are involved but since these qualia do not have any directional flavor, spin is probably not involved. This would give c 3×4 basic combinations are possible and can certainly explain the 5 or 6 basic tastes (counted as the number of different receptors). Whether there is a finite number of odours or not has been a subject of a continual debate and it might be that odours already correspond to a distribution of primary qualia for the receptor cell. That odours are coded by nerve pulse patterns for a group of neurons [J51] would conform with this picture.

3. Hearing seems to represent a rather colorless quale so that electroweak isospin suggests again itself. If we had a need to hear transversely polarized sound also spin would be involved. Cilia are involved also with hair cells acting as sensory receptors in the auditory system and vestibular system. In the case of hearing the receptor itself does not fire but induces a firing of the higher level neuron. The temporal pattern of qualia mental images could define the pitch of the sound whereas the intensity would correspond to the number of flux tube connections generated.

   The modulation of Josephson frequencies -rather than Josephson frequencies as such- would code for the pitch and the total intensity of the Josephson radiation for the intensity of the sound and in fact any quale. Pitch represents non-local information and the qualia sub-selves should be negentropically entangled in time direction. If not, the experience corresponds to a sequence of sound pulses with no well-defined pitch and responsible for the rhythmic aspects of music. Right brain sings-left brain talks metaphor would suggests that right and left brain have different kind of specializations already at the level of sensory receptors.

4. Somato-sensory system gives rise to tactile qualia like pain, touch, temperature, proprioception (body position). There are several kinds of receptors: nocireceptors, mechanoreceptors,

thermoreceptors, etc... Many of these qualia have also emotional coloring and it might be that the character of entanglement involved (negentropic/entropic defines the emotional color of the quale. If this is the case, one might consider a pure quale of touch as something analogous to hearing quale. One can argue that directionality is basic aspect of some of these qualia -say sense of touch- so that spin could be involved besides electroweak quantum numbers. The distribution of these qualia for the receptor neuron might distinguish between different tactile qualia.

2.4.5 Recent TGD based view about qualia

The TGD inspired theory of qualia [K41] has evolved gradually and the recent view differs from the above described picture in some aspects.

1. The original vision was that qualiaandother aspects of consciousness experience are determined by the change of quantum state in the reduction: the increments of quantum numbers would determine qualia. I had not yet realized that repeated state function reduction (Zeno effect) realized in ZEO is central for consciousness. The objection was that qualia change randomly from reduction to reduction.

2. Later I ended up with the vision that the rates for the changes of quantum numbers would determine qualia: this idea was realized in terms of sensory capacitor model in which qualia would correspond to kind of generalized di-electric breakdown feeding to subsystem responsible for quale quantum numbers characterizing the quale. The Occamistic objection is that the model brings in an additional element not present in quantum measurement theory.

3. The view that emerged while writing the critics of IIT of Tononi is that qualia correspond to the quantum numbers measured in the state function reduction. That in ZEO the qualia remain the same for the entire sequence of repeated state function reductions is not a problem since qualia are associated with sub-self (sub-CD), which can have lifetime of say about .1 seconds! Only the generalization of standard quantum measurement theory is needed to reduce the qualia to fundamental physics. This for instance supports the conjecture that visual colors correspond to QCD color quantum numbers. This makes sense in TGD framework predicting a scaled variants of QCD type physics even in cellular length scales.

   This view implies that the model of sensory receptor based on the generalization of di-electric breakdown [K59] is wrong as such since the rate for the transfer of the quantum numbers would not define the quale. A possible modification of the model simple: the analog of di-electric breakdown generates Bose-Einstein condensate and the quantum numbers for the BE condensate give rise to qualia assignable to sub-self.

2.5 Could Cell Membrane Correspond To Almost Vacuum Extremal?

The question whether cell membrane or even cell could correspond almost vacuum extremal of Kähler action (in some cases) was the question which led to the realization that the frequencies of peak sensitivity for photoreceptors correspond to the Josephson frequencies of biologically important ions if one accepts that the value of the Weinberg angle equals to $sin^2(\theta_W) = .0295$ instead of the value .23 in the normal phase, in which the classical electromagnetic field is proportional to the induced Kähler form of CP_2 in a good approximation. Another implication made possible by the large value of Planck constant is the identification of Josephson photons as the counterparts of bio-photons one one hand and those of EEG photons on the other hand. These observation in turn led to a detailed model of sensory qualia and of sensory receptor. Therefore the core of this argument deserves to be represented also here although it has been discussed in [K82].

2.5.1 Cell Membrane As Almost Vacuum Extremal

Although the fundamental role of vacuum extremals for quantum criticality and life has been obvious from the beginning, it took a long time to realize how one could model living cell as this kind of system.

1. Classical electric fields are in a fundamental role in biochemistry and living biosystems are typically electrets containing regions of spontaneous electric polarization. Fröhlich [I66] proposed that oriented electric dipoles form macroscopic quantum systems with polarization density serving as a macroscopic order parameter. Several theories of consciousness share this hypothesis. Experimentally this hypothesis has not been verified.

2. TGD suggests much more profound role for the unique di-electric properties of the biosystems. The presence of strong electric dipole fields is a necessary prerequisite for cognition and life and could even force the emergence of life. Strong electric fields imply also the presence of the charged wormhole BE condensates: the surface density of the charged wormholes on the boundary is essentially equal to the normal component of the electric field so that wormholes are in some sense "square root" of the dipole condensate of Fröhlich! Wormholes make also possible pure vacuum polarization type dipole fields: in this case the magnitudes of the em field at the two space-time sheets involved are same whereas the directions of the fields are opposite. The splitting of wormhole contacts creates fermion pairs which might be interpreted as cognitive fermion pairs. Also microtubules carry strong longitudinal electric fields. This formulation emerged much before the identification of ordinary gauge bosons and their superpartners as wormhole contacts.

Cell membrane is the basic example about electret and one of the basic mysteries of cell biology is the resting potential of the living cell. Living cell membranes carry huge electric fields: something like 10^7 Volts per meter. For neuron resting potential corresponds to about.07 eV energy gained when unit charge travels through the membrane potential. In TGD framework it is not at all clear whether the presence of strong electromagnetic field necessitates the presence of strong Kähler field. The extremely strong electric field associated with the cell membrane is not easily understood in Maxwell's theory and almost vacuum extremal property could change the situation completely in TGD framework.

1. The configuration could be a small deformation of vacuum extremal so that the system would be highly critical as one indeed expects on basis of the general visiona about living matter as a quantum critical system. For vacuum extremals classical em and Z^0 fields would be proportional to each other. The second half of Maxwell's equations is not in general satisfied in TGD Universe and one cannot exclude the presence of vacuum charge densities in which case elementary particles as the sources of the field would not be necessarily. If one assumes that this is the case approximately, the presence of Z^0 charges creating the classical Z^0 fields is implied. Neutrinos are the most candidates for the carrier of Z^0 charge. Also nuclei could feed their weak gauge fluxes to almost non-vacuum extremals but not atomic electrons since this would lead to dramatic deviations from atomic physics. This would mean that weak bosons would be light in this phase and also Weinberg angle could have a non-standard value.

2. There are also space-time surfaces for CP_2 projection belongs to homologically non-trivial geodesic sphere. In this case classical Z^0 field can vanish [L2], [L2] and the vision has been that it is sensible to speak about two basic configurations.

   (a) Almost vacuum extremals (homologically trivial geodesic sphere).

   (b) Small deformations of non-vacuum extremals for which the gauge field has pure gauge Z^0 component (homologically non-trivial geodesic sphere).

   The latter space-time surfaces are excellent candidates for configurations identifiable as TGD counterparts of standard electroweak physics. Note however that the charged part of electroweak fields is present for them.

3. To see whether the latter configurations are really possible one must understand how the gauge fields are affected in the color rotation.

(a) The action of color rotations in the holonomy algebra of CP_2 is non-trivial and corresponds to the action in $U(2)$ sub-group of $SU(3)$ mapped to $SU(2)_L \times U(1)$. Since the induced color gauge field is proportional to Kähler form, the holonomy is necessary Abelian so that also the representation of color rotations as a sub-group of electro-weak group must correspond to a local $U(1)$ sub-group local with respect to CP_2 point.

(b) Kähler form remains certainly invariant under color group and the right handed part of Z^0 field reducing to $U(1)_R$ sub-algebra should experience a mere Abelian gauge transformation. Also the left handed part of weak fields should experience a local $U(1)_L$ gauge rotation acting on the neutral left handed part of Z^0 in the same manner as it acts on the right handed part. This is true if the $U(1)_L$ sub-group does not depend on point of CP_2 and corresponds to Z^0 charge. If only Z^0 part of the induced gauge field is non-vanishing as it can be for vacuum extremals then color rotations cannot change the situation. If Z^0 part vanishes and non-vacuum extremal is in question, then color rotation rotation of W components mixing them but acts as a pure $U(1)$ gauge transformation on the left handed component.

(c) It might not be without importance that for any partonic 2-surface induced electroweak gauge fields have always U(1) holonomy, which could allow to define what neutral part of induced electroweak gauge field means locally. This does not however hold true for the 4-D tangent space distribution. In any case, the cautious conclusion is that there are two phases corresponding to nearly vacuum extremals and small deformations of extremals corresponding to homologically non-trivial geodesic spheres for which the neutral part of the classical electro-weak gauge field reduces to photon field.

4. The unavoidable presence of long range Z^0 fields would explain large parity breaking in living matter, and the fact that neutrino Compton length is of the order of cell size would suggest the possibility that within neutrino Compton electro-weak gauge fields or even longer scales could behave like massless fields. The explanation would be in terms of the different ground state characterized also by a different value of Weinberg angle. For instance, of the p-adic temperature of weak bosons corresponds to $T_p = 1/2$, the mass scale would be multiplied by a factor $\sqrt{M_{89}}$ and Compton lengths of weak bosons would be around 10^{-4} meters corresponding to the size scale of a large neuron. If the value of Planck constant is also large then the Compton length increases to astrophysical scale.

5. From the equations for classical induced gauge fields in terms of Kähler form and classical Z^0 field [L2] , [L2]

$$\gamma = 3J - \frac{p}{2}Z^0 \quad , \quad Q_Z = I_L^3 - pQ_{em} \quad , \quad p = sin^2(\theta_W) \tag{2.5.1}$$

it follows that for the vacuum extremals the part of the classical electro-weak force proportional to the electromagnetic charge vanishes for $p = 0$ so that only the left-handed couplings to the weak gauge bosons remain. The absence of electroweak symmetry breaking and vanishing or at least smallness of p would make sense below the Compton length of dark weak bosons. If this picture makes sense it has also implications for astrophysics and cosmology since small deformations of vacuum extremals are assumed to define the interesting extremals. Dark matter hierarchy might explain the presence of unavoidable long ranged Z^0 fields as being due to dark matter with arbitrarily large values of Planck constant so that various elementary particle Compton lengths are very long.

6. The simplest option is that the dark matter -say quarks with Compton lengths of order cell size and Planck constant of order $10^7\hbar_0$ - are responsible for dark weak fields making almost vacuum extremal property possible. The condition that Josephson photons correspond to EEG frequencies implys $\hbar \sim 10^{13}\hbar_0$ and would mean the scaling of intermediate gauge boson Compton length to that corresponding to the size scale of a larger neuron. The quarks involved with with DNA as topological quantum computer model could be in question and membrane potential might be assignable to the magnetic flux tubes. The ordinary ionic

currents through cell membrane -having no coupling to classical Z^0 fields and not acting as its sourse- would be accompanied by compensating currents of dark fermions taking care that the almost vacuum extremal property is preserved. The outcome would be large parity breaking effects in cell scale from the left handed couplings of dark quarks and leptons to the classical Z^0 field. The flow of Na^+ ions during nerve pulse could take along same dark flux tube as the flow of dark quarks and leptons. This near vacuum extremal property might be fundamental property of living matter at dark space-time sheets at least.

Could nuclei and neutrinos couple to light variants of weak gauge fields in the critical phase?

One of the hard-to-kill ideas of quantum TGD inspired model of quantum biology is that neutrinos might have something do with hearing and cognition. This proposal looks however unrealistic in the recent vision. I would be more than happy to get rid of bio-neutrinos but the following intriguing finding does not allow me to have this luxury.

1. Assume that the endogenous magnetic field $B_{end} = .2$ Gauss is associated with a nearly vacuum extremal and therefore accompanied by $B_Z = 2B_{end}/p$. Assume for definiteness $m_\nu = .3$ eV and $p = sin^2(\theta_W) = .23$. The neutrino cyclotron frequency is given by the following expression

$$f_\nu = \frac{m_e}{m_\nu}\frac{1}{2sin^2(\theta_W)}f_e \quad .$$

From $f_e \simeq .57\times$ MHz and $p = sin^2(\theta_W) = .23$ one obtains $E_\nu = 1.7 \times 10^{-2}$ eV, which is roughly one third to the Josephson frequency of electron assignable to cell membrane. Could Josephson frequency of cell membrane excite neutrino cyclotron transitions?

2. The model for photoreceptors to be discussed below forces to conlude that the value of Weinberg angle in the phase near vacuum extremal must be $p = .0295$ if one wants to reproduces the peak energies of photoreceptors as Josephson frequencies of basic biological ions. This would predict $E_\nu = .41$ eV, which is rather near to the metabolic energy quantum. The non-relativistic formula however fails in this case and one must use the relativistic formula giving

$$E = \sqrt{g_Z Q_Z B_Z 2\pi} \simeq .48 \ \ eV$$

giving the metabolic energy quantum. Does this mean that Z^0 cyclotron frequency for neutrino is related to the transfer of metabolic energy using Z^0 MEs in the phase near vacuum extremals.

3. Josephson frequency is proportional to $1/\hbar$, whereas neutrino cyclotron frequency does not depend on $\hbar$ at non-relativistic energies. For larger values of $\hbar$ the neutrino becomes relativistic so that the mass in the formula for cyclotron frequency must be replaced with energy. This gives

$$E = \sqrt{n}r^{1/2}\sqrt{g_Z Q_Z B_Z 2\pi} \simeq r^{1/2} \times .48 \ \ eV \ \ , \ \ r = \sqrt{\hbar/\hbar_0} \ \ .$$

Here n refers to the cyclotron harmonic.

These observations raise the question whether the three frequencies with maximum response assignable to the three different types of receptors of visible light in retina could correspond to the three cyclotron frequencies assignable to the three neutrinos with different mass scales? The first objection is that the dependence on mass disappears completely at the relativistic limit. The second objection is that the required value value of Planck constant is rather small and far from being enough to have electroweak boson Compton length of order cell size. One can of course ask whether the electroweak gauge bosons are actually massless inside almost vacuum extremals. If fermions -including neutrino- receive their masses from p-adic thermodynamics then massless electroweak gauge bosons would be consistent with massive fermions. Vacuum extremals are indeed analogous to the unstable extrema of Higgs potential at which the Higgs vacuum expecation vanishes so that this interpretation might make sense.

Ionic Josephson frequencies defined by the resting potential for nearly vacuum extremals

If cell membrane corresponds to an almost vacuum extremal, the membrane potential potential is replaced with an effective resting potential containing also the Z^0 contribution proportional to the ordinary resting potential. The surprising outcome is that one could understand the preferred frequencies for photo-receptors [J6] as Josephson frequencies for biologically important ions. Furthermore, most Josephson energies are in visible and UV range and the interpretation in terms of bio-photons is suggestive. If the value of Planck constant is large enough Josephson frequencies are in EEG frequency range so that bio-photons and EEG photons could be both related to Josephson photons with large $\hbar$.

1. One must assume that the interior of the cell corresponds to many fermion state -either a state filled with neutrinos up to Fermi energy or Bose-Einstein condensate of neutrino Cooper pairs creating a harmonic oscillator potential. The generalization of nuclear harmonic oscillator model so that it applies to multi-neutrino state looks natural.

2. For exact vacuum extremals elementary fermions couple only via left-handed isospin to the classical Z^0 field whereas the coupling to classical em field vanishes. Both K_+, Na_+, and Cl_- $A-Z=Z+1$ so that by p-n pairing inside nucleus they have the weak isospin of neuron (opposite to that of neutrino) whereas Ca_{++} nucleus has a vanishing weak isospin. This might relate to the very special role of Ca_{++} ions in biology. For instance, Ca_{++} defines an action potential lasting a time of order.1 seconds whereas Na_+ defines a pulse lasting for about 1 millisecond [J2]. These time scales might relate to the time scales of CDs associated with quarks and electron.

3. The basic question is whether only nuclei couple to the classical Z^0 field or whether also electrons do so. If not, then nuclei have a large effective vector coupling to em field coming from Z^0 coupling proportional to the nuclear charge increasing the value of effective membrane potential by a factor of order 100. If both electrons and nuclei couple to the classical Z^0 field, one ends up with difficulties with atomic physics. If only quarks couple to the Z^0 field and one has $Z^0=-2\gamma/p$ for vacuum extremals, and one uses average vectorial coupling $\langle I_L^3\rangle = \pm 1/4$ with + for proton and - for neutron, the resulting vector coupling is following

$$\begin{aligned} (\frac{Z-N}{4}-pZ)Z^0+q_{em}\gamma &= Q_{eff}\gamma \ , \\ Q_{eff} &= -\frac{Z-N}{2p}+2Z+q_{em} \ . \end{aligned} \tag{2.5.2}$$

Here γ denotes em gauge potential. For K^+, Cl^-, Na^+, Ca^{++} one has $Z=(19,17,11,20)$, $Z-N=(-1,-1,-1,0)$, and $q_{em}=(1,-1,1,2)$. **Table 2.1** below gives the values of Josephson energies for some values of resting potential for $p=.23$. Rather remarkably, they are in IR or visible range. This is basically due to the large value of weak isospin for nuclei.

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2.5.2 Are Photoreceptors Nearly Vacuum Extremals?

In Hodgkin-Huxley model ionic currents are Ohmian currents. If one accepts the idea that the cell membrane acts as a Josephson junction, there are also non-dissipative oscillatory Josephson currents of ions present, which run also during flow equilibrium for the ionic parts of the currents. A more radical possibility is that the dominating parts of the ionic currents are oscillatory Josephson currents so that no metabolic energy would be needed to take care that density gradients for ions are preserved. Also in this case both nearly vacuum extremals and extremals with nearly vanishing Z^0 field can be considered. Since sensory receptors must be highly critical the natural question is whether they could correspond to nearly vacuum extremals. The quantitative success of the following model for photoreceptors supports this idea.

$E(Ion)/eV$	$V=-40\ mV$	$V=-60\ mV$	$V=-70\ mV$
Na^+	1.01	1.51	1.76
Cl^-	1.40	2.11	2.46
K^+	1.64	2.47	2.88
Ca^{++}	1.68	2.52	2.94

Table 2.1: Values of the Josephson energy of cell membrane for some values of the membrane voltage for $p=.23$. The value $V=-40$ mV corresponds to the resting potential for photoreceptors and $V=-70$ mV to the resting state of a typical neuron.

Photoreceptors can be classified to three kinds of cones responsible for color vision and rods responsible for black-white vision. The peak sensitivities of cones correspond to wavelengths (405, 535, 565) nm and energies (3.06, 2.32, 2.19) eV. The maximum absorption occurs in the wave length range 420-440 nm, 534-545 nm, 564-580 nm for cones responsible for color vision and 498 nm for rods responsible black-white vision [L37, J6]. The corresponding photon energies are (2.95, 2.32, 2.20) eV for color vision and to 2.49 eV for black-white vision. For frequency distribution the maxima are shifted from these since the maximum condition becomes $dI/d\lambda + 2I/\lambda = 0$, which means a shift to a larger value of λ, which is largest for smallest λ. Hence the energies for maximum absorbance are actually lower and the downwards shift is largest for the highest energy.

From **Table 2.1** it is clear that the energies of Josephson photons are in visible range for reasonable values of membrane voltages, which raises the question whether Josephson currents of nuclei in the classical em and Z^0 fields of the cell membrane could relate to vision.

Consider first the construction of the model.

1. Na$^+$ and Ca^{++} currents are known to present during the activation of the photoreceptors. Na^+ current defines the so called dark current [J6] reducing the membrane resting potential below its normal value and might relate to the sensation of darkness as eyes are closed. Hodgkin-Huxley model predicts that also K^+ current is present. Therefore the Josephson energies of these three ion currents are the most plausible correlates for the three colors.

2. One ends up with the model in the following manner. For Ca^{++} the Josephson frequency does not depend on p and requiring that this energy corresponds to the energy 2.32 eV of maximal sensitivity for cones sensitive to green light fixes the value of the membrane potential during hyper-polarization to $V=.055$ V, which is quite reasonable value. The value of the Weinberg angle parameter can be fixed from the condition that other peak energies are reproduced optimally. The result of $p=.0295$.

The predictions of the model come as follows summarized also by the **Table 2.2**.

1. The resting potential for photoreceptors is $V=-40$ mV [J7]. In this case all Josephson energies are below the range of visible frequencies for $p=.23$. Also for maximal hyper-polarization Na^+ Josephson energy is below the visible range for this value of Weinberg angle.

2. For $V=-40$ mV and $p=.0295$ required by the model the energies of Cl^- and K^+ Josephson photons correspond to red light. 2 eV for Cl^- corresponds to a basic metabolic quantum. For Na^+ and Ca^{++} the wave length is below the visible range. Na^+ Josephson energy is below visible range. This conforms with the interpretation of Na^+ current as a counterpart for the sensation of darkness.

3. For $V=-55$ mV - the threshold for the nerve pulse generation- and for $p=.0295$ the Josephson energies of Na^+, Ca^{++}, and K^+ a correspond to the peak energies for cones sensitive to red, green, and blue respectively. Also Cl^- is in the blue region. Ca^{++} Josephson energy can be identified as the peak energy for rods. The increase of the hyper-polarization to $V=-59$ mV reproduces the energy of the maximal wave length response exactly. A possible interpretation is that around the criticality for the generation of the action potential ($V\simeq -55$ mV) the qualia would be generated most intensely since the Josephson currents

Ion	Na^+	Cl^-	K^+	Ca^{++}
$E_J(.04\ mV, p = .23)/eV$	1.01	1.40	1.51	1.76
$E_J(.065\ V, p = .23)/eV$	1.64	2.29	2.69	2.73
$E_J(40\ mV, p = .0295)/eV$	1.60	2.00	2.23	1.68
$E_J(50\ mV, p = .0295)/eV$	2.00	2.49	2.79	2.10
$E_J(55\ mV, p = .0295)/eV$	2.20	2.74	3.07	2.31
$E_J(65\ mV, p = .0295)/eV$	2.60	3.25	3.64	2.73
$E_J(70\ mV, p = .0295)/eV$	2.80	3.50	3.92	2.94
$E_J(75\ mV, p = .0295)/eV$	3.00	3.75	4.20	3.15
$E_J(80\ mV, p = .0295)/eV$	3.20	4.00	4.48	3.36
$E_J(90\ mV, p = .0295)/eV$	3.60	4.50	5.04	3.78
$E_J(95\ mV, p = .0295)/eV$	3.80	4.75	5.32	3.99
Color	R	G	B	W
E_{max}	2.19	2.32	3.06	2.49
energy-interval/eV	1.77-2.48	1.97-2.76	2.48-3.10	

Table 2.2: Table gives the prediction of the model of photoreceptor for the Josephson energies for typical values of the membrane potential. For comparison purposes the energies E_{max} corresponding to peak sensitivities of rods and cones, and absorption ranges for rods are also given. R, G, B, W refers to red, green, blue, white. The values of Weinberg angle parameter $p = sin^2(\theta_W)$ are assumed to be .23 and.0295. The latter value is forced by the fit of Josephson energies to the known peak energies if one allows that ions - rather than their Cooper pairs - are charge carriers.

would be strongest and induce Josephson radiation inducing the quale in other neurons of the visual pathway at the verge for the generation of action potential. This supports the earlier idea that visual pathways defines a neural window. Josephson radiation could be interpreted as giving rise to bio-photons (energy scale is correct) and to EEG photons (for large enough values of $\hbar$ the frequency scales is that of EEG).

4. In a very bright illumination the hyper-polarization is $V = -65$ mV [J7], which the normal value of resting potential. For this voltage Josephson energies are predicted to be in UV region except in case of Ca^{++}. This would suggests that only the quale "white" is generated at the level of sensory receptor: very intense light is indeed experienced as white.

The model reproduces basic facts about vision assuming that one accepts the small value of Weinberg angle, which is indeed a natural assumption since vacuum extremals are analogous to the unstable extrema of Higgs potential and should correspond to small Weinberg angle. It deserves to be noticed that neutrino Josephson energy is 2 eV for $V = -50$ mV, which correspond to color red. 2 eV energy defines an important metabolic quantum.

It interesting to try to interpret the resting potentials of various cells in this framework in terms of the Josephson frequencies of various ions.

1. The maximum value of the action potential is +40 mV so that Josephson frequencies are same as for the resting state of photoreceptor. Note that the time scale for nerve pulse is so slow as compared to the frequency of visible photons that one can consider that the neuronal membrane is in a state analogous to that of a photoreceptor.

2. For neurons the value of the resting potential is -70 mV. Na^+ and Ca^{++} Josephson energies 2.80 eV and 2.94 eV are in the visible range in this case and correspond to blue light. This does not mean that Ca^{++} Josephson currents are present and generate sensation of blue at neuronal level: the quale possibly generated should depend on sensory pathway. During the hyper-polarization period with -75 mV the situation is not considerably different.

3. The value of the resting potential is -95 mV for skeletal muscle cells. In this case Ca^{++} Josephson frequency corresponds to 4 eV metabolic energy quantum as **Table 2.1** shows.

4. For smooth muscle cells the value of resting potential is -50 mV. In this case Na^+ Josephson frequency corresponds to 2 eV metabolic energy quantum.

5. For astroglia the value of the resting potential is -80/-90 mV for astroglia. For -80 mV the resting potential for Cl^- corresponds to 4 eV metabolic energy quantum. This suggests that glial cells could also provide metabolic energy as Josephson radiation to neurons.

6. For all other neurons except photo-receptors and red blood cells Josephson photons are in visible and UV range and the natural interpretation would be as bio-photons. The bio-photons detected outside body could represent sensory leakage. An interesting question is whether the IR Josephson frequencies could make possible some kind of IR vision.

To sum up, the basic criticism against the model is that the value of Weinberg angle must be by a factor of 1/10 smaller than the standard model value, and at this moment it is difficult to say anything about its value for nearly vacuum extremals.

A possible cure could be that the voltage is not same for different ions. This is possible since at microscopic level the Josephson junctions correspond to transmembrane proteins acting as channels and pumps. The membrane potential through receptor protein is different for color receptors. For this option one would have the correspondences
$Na^+ \leftrightarrow$ 2.19 eV (R) and $eV = 86.8$ eV,
$Cl^- \leftrightarrow$ 2.32 eV (G) and $eV = 65.8$ eV,
$K^+ \leftrightarrow$ 2.49 eV (W) and $eV = 60.2$ eV,
$Ca^{++} \leftrightarrow$ 3.06 eV (B) and $eV = 67.3$ meV.
For Na^+ the value of the membrane potential is suspiciously large.

It is interesting to look what happens when the model is generalized so that Josephson energy includes the difference of cyclotron energies at the two sides of the cell membrane and Weinberg angle has its standard model value.

1. Consider first *near to vacuum extremals*. In the formula for cyclotron frequencies in the effective magnetic field the factor Z/A in the formula of is replaced with

$$\frac{\frac{N-Z}{2p} + 2Z + q_{em}}{A} ,$$

which is not far from unity so that the cyclotron frequency would be near to that for proton for all ions. Also neutral atoms would experience classical and magnetic Z^0 fields. Cyclotron frequency would be almost particle independent so that cyclotron contribution gives an almost constant shift to the generalized Josephson energy. When the difference of cyclotron energies vanishes, the model reduces to that discussed above.

The weak independence of the cyclotron frequency on particle properties does not conform with the idea that EEG bands correspond to bosonic ions or Cooper pairs of fermionic ions.

2. For *far from vacuum extremals* the proportionality of cyclotron energy to h_{eff} and B_{end} allows easy reproduction the energies for which photon absorption is maximal if one allows the cyclotron energies to differ at the two sides of the membrane for sensory receptors.

A remark about decade later: The model just discussed neglects the fact that superconductivity requires that Cooper pairs of fermionic ions are present unless one assumes that the nuclei are bosonic counterparts of fermionic nuclei with same chemical properties - TGD inspired nuclear physics indeed predicts this kind of exotic nuclei [L3]. For Cooper pairs of Na^+, Cl^-, and K^+, $p = .23$ and $E_J = .04$ eV assignable to visual receptors the Josephson energies are doubled being $2.02, 2.80, 3.02$ eV. These energies could correspond to peak energies for visible photons. The assumption of ionic Cooper pairs is rather attractive since it would allow to avoid two questionable assumptions.

For electron the Josephson energy would be scaled by a factor $-1 + 1/2p$ to $E_J = 1.0859 \times eV_{rest}$ for $p = .2397$. For neutrino the energy would be given by $E_J = -0.0859 \times V_{rest}$: for $p = 1/4$ it would vanish by the vanishing of vectorial part of Z^0 charge. For proton the energy would be $E_J = (3 - 1/2p)V_{rest} = .914 \times V_{rest}$ and for neutron $E_J = V_{rest}/2p = 2.086 \times V_{rest}$.

2.6 Pollack's Findings About Fourth Phase Of Water And The Model Of Cell

The discovery of negatively charged exclusion zone formed in water bounded by gel phase has led Pollack to propose the notion of gel like fourth phase of water. In this article this notion is discussed in TGD framework. The proposal is that the fourth phase corresponds to negatively charged regions - exclusion zones - with size up to 100-200 microns generated when energy is fed into the water - say as radiation, in particular solar radiation. The stoichiometry of the exclusion zone is $H_{1.5}O$ and can be understood if every fourth proton is dark proton residing at the flux tubes of the magnetic body assignable to the exclusion zone and outside it.

This leads to a model for prebiotic cell as exclusion zone. Dark protons are proposed to form dark nuclei whose states can be grouped to groups corresponding to DNA, RNA, amino-acids, and tRNA and for which vertebrate genetic code is realized in a natural manner. The voltage associated with the system defines the analog of membrane potential, and serves as a source of metabolic energy as in the case of ordinary metabolism. The energy is liberated in a reverse phase transition in which dark protons transform to ordinary ones. Dark proton strings serve as analogs of basic biopolymers and one can imagine analog of bio-catalysis with enzymes replaced with their dark analogs. The recent discovery that metabolic cycles emerge spontaneously in absence of cell support this view.

One can find a biographical sketch [I20] (`http://tinyurl.com/ycqtuchp`) giving a list of publications containing items related to the notions of exclusion zone and fourth phase of water discussed in the talk.

2.6.1 Pollack's Findings

I list below some basic experimental findings about fourth gel like phase of water made in the laboratory led by Gerald Pollack [L15].

1. In water bounded by a gel a layer of thickness up to 100-200 microns is formed. All impurities in this layer are taken outside the layer. This motivates the term "exclusion zone". The layer consists of layers of molecular thickness and in these layers the stoichiometry is $H_{1.5}O$. The layer is negatively charged. The outside region carries compensating positive charge. This kind of blobs are formed in living matter. Also in the splitting of water producing Brown's gas negatively charged regions are reported to emerge [H20, H2].

2. The process requires energy and irradiation by visible light or thermal radiation generates the layer. Even the radiation on skin can induce the phase transition. For instance, the blood flow in narrow surface veins requires metabolic energy and irradiation forces the blood to flow.

3. The layer can serve as a battery: Pollack talks about a form of free energy deriving basically from solar radiation. The particles in the layer are taken to the outside region, and this makes possible disinfection and separation of salt from sea water. One can even understand how clouds are formed and mysteries related to the surface tension of water as being due the presence of the layer formed by $H_{1.5}O$.

4. In the splitting of water producing Brown's gas [H20, H2] having a natural identification as Pollack's fourth phase of water the needed energy can come from several alternative sources: cavitation, electric field, etc...

2.6.2 Dark Nuclei And Pollack's Findings

While listening the lecture of Pollack I realized that a model for dark water in term of dark proton sequences is enough to explain the properties of the exotic water according to experiments done in the laboratory of Pollack. There is no need to assume sequences of half-dark water molecules containing one dark proton each.

Model for the formation of exclusion zones

The data about formation of exclusion zones allows to construct a more detailed model for what might happen in the formation of exclusion zones.

1. The dark proton sequences with dark proton having size of order atomic nucleus would reside at the flux tubes of dark magnetic field which is dipole like field in the first approximation and defines the magnetic body of the negatively charged water blob. This explains the charge separation if the flux tubes have length considerably longer than the size scale of the blob which is given by size of small cell. In the model inspired by Moray B. King's lectures charge separation is poorly understood.

2. An interesting question is whether the magnetic body is created by the electronic currents or whether it consists of flux tubes carrying monopole flux: in the latter case no currents would be needed. This is obviously purely TGD based possibility and due to the topology of CP_2.

3. This means that in the model inspired by the lectures of Moray B. King discussed above, one just replaces the sequences of partially dark water molecules with sequences of dark protons at the magnetic body of the $H1.5O$ blob. The model for the proto-variants of photosynthesis and metabolism remain as such. Also now genetic code would be realized [K44, L3].

4. The transfer of impurities from the exclusion zone could be interpreted as a transfer of them to the magnetic flux tubes outside the exclusion zone as dark matter.

These primitive forms of photosynthesis and metabolism form could be key parts of their higher level chemical variants. Photosynthesis by irradiation would induce a phase transition generating dark magnetic flux tubes (or transforming ordinary flux tubes to dark ones) and the dark proton sequences at them. Metabolism would mean burning of the resulting blobs of dark water to ordinary water leading to the loss of charge separation. This process would be analogous to the catabolism of organic polymers liberating energy. Also organic polymers in living matter carry their metabolic energy as dark proton sequences: the layer could also prevent their hydration. That these molecules are typically negatively charged would conform with the idea that dark protons at magnetic flux tubes carry the metabolic energy.

The liberation of energy would involve increase of the p-adic prime characterizing the flux tubes and reduction of Planck constant so that the thickness of the flux tubes remains the same but the intensity of the magnetic field is reduced. The cyclotron energy of dark protons is liberated in coherent fashion and in good approximation the frequencies of the radiation corresponds to multiplies of cyclotron frequency: this prediction is consistent with that in the original model for the findings of Blackman and others [J23].

The phase transition generating dark magnetic flux tubes containing dark proton sequences would be the fundamental step transforming inanimate matter to living matter and the fundamental purpose of metabolism would be to make this possible.

Minimal metabolic energy consumption and the value of membrane potential

This picture raises a question relating to the possible problems with physiological temperature.

1. The Josephson radiation generated by cell membrane has photon energies coming as multiples of ZeV, where V is membrane potential about.06 V and $Z = 2$ is the charge of electron Cooper pair. This gives $E = .12$ eV.

2. There is a danger that thermal radiation masks Josephson radiation. The energy for photons at the maximum of the energy density of blackbody radiation as function of frequency is given as the maximum of function $x^3/(e^x - 1)$, $x = E/T$ given by $e^{-x} + x/3 - 1 = 0$. The maximum is given approximately by $x = 3$ and thus $E_{max} \simeq 3T$ (in units $c = 1, k_B = 1$). At physiological temperature $T = 310$ K (37 C) this gives .1 eV, which is slightly below Josephson energy: living matter seems to have minimized the value of Josephson energy - presumably to minimize metabolic costs. Note however that for the thermal energy density as function of *wavelength* the maximum is at $E \simeq 5T$ corresponding to 1.55 eV which is larger than Josephson energy. The situation is clearly critical.

3. One can ask whether also a local reduction of temperature around cell membrane in the fourth phase of water is needed.

   "Electric expansion" of water giving rise to charge separation and presumably creating fourth phase of water is reported to occur [H20, H2].

   (b) Could the electric expansion/phase transition to dark phase be adiabatic involving therefore no heat transfer between the expanding water and environment? If so, it would transform some thermal energy of expanding water to work and reduce its temperature. The formula for the adiabatic expansion of ideal gas with f degrees of freedom for particle ($f = 3$ if there are no other than translational degrees of freedom) is $(T/T_0) = (V/V_0)^{-\gamma}$, $\gamma = (f+2)/f$. This gives some idea about how large reduction of temperature might be involved. If p-adic scaling for water volume by a power of two takes place, the reduction of temperature can be quite large and it does not look realistic.

   (c) The electric expansion of water need not however involve the increase of Planck constant for water volume. Only the Planck constant for flux tubes must increase and would allow the formation of dark proton sequences and the generation of cyclotron Bose-Einstein condensates or their dark analog in which fermions (electrons in particular) effectively behave as bosons (the anti-symmetrization of wave function would occur in dark degrees of freedom corresponding to multi-sheeted covering formed in the process).

2.6.3 Fourth Phase Of Water And Pre-Biotic Life In TGD Universe

Metabolism and fourth phase of water

If the fourth phase of water defines pre-biotic life form then the phase transition generating fourth phase of water and its reversal are expected to be fundamental elements of the ordinary metabolism, which would have developed from the pre-biotic metabolism. The following arguments conforms with this expectation.

1. Cell interiors, in particular the interior of the inner mitochondrial membrane are negatively charged as the regions formed in Pollack's experiments. Furthermore, the citric acid cycle, (`http://tinyurl.com/y8ubjgnc`), which forms the basic element of both photosynthesis (`http://tinyurl.com/yauwzkho`) and cellular respiration `http://tinyurl.com/ybeefxmb`, involves electron transport chain (`http://tinyurl.com/yat3m4vk`) in which electron loses gradually its energy via production of NADP and proton at given step. Protons are pumped to the other side of the membrane and generates proton gradient serving as metabolic energy storage just like battery. The interpretation for the electron transport chain in terms of Pollack's experiment would be in terms of generation of dark protons at the other side of the membrane.

2. When ATP is generated from ADP three protons per ATP flow back along the channel formed by the ATP synthase molecule (`http://tinyurl.com/yd5ndcyk`) (perhaps Josephson junction) and rotate the shaft of a "motor" acting as a catalyst generating three ATP molecules per turn by phosphorylating ADP. The TGD based interpretation is that dark protons are transformed back to ordinary ones and possible negentropic entanglement is lost.

3. ATP is generated also in glycolysis (`http://tinyurl.com/ybzgdgve`), which is ten-step process occurring in cytosol so that membrane like structure need not be involved. Glycolysis involves also generation of two NADH molecules and protons. An open question (to me) is whether the protons are transferred through an endoplasmic reticulum or from a region of ordered water (fourth phase of water) to its exterior so that it would contribute to potential gradient and could go to magnetic flux tubes as dark proton. This would be natural since glycolysis is realized for nearly all organisms and electron transport chain is preceded by glycolysis and uses as input the output of glycolysis (two pyruvate molecules (`http://tinyurl.com/y8v7aq9s`)).

4. Biopolymers - including DNA and ATP - are typically negatively charged. They could thus be surrounded by fourth phase of water and neutralizing protons would reside at the magnetic bodies. This kind of picture would conform with the idea that the fourth phase (as also magnetic body) is fractal like. In phosphorylation the metabolic energy stored to a potential difference is transferred to shorter length scales (from cell membrane scale to molecular scale).

In glycolysis (`http://tinyurl.com/ybzgdgve`) the net reaction $C_6H_{12}O_6{+}6O_2 \rightarrow 6CO_2(g){+}6H_2O(l){+}heat$ takes place. The Gibbs free energy change is $\Delta G = -2880$ kJ per mole of $C_6H_{12}O_6$ and is negative so that the process takes place spontaneously. Single glucose molecule is theoretized to produce $N = 38$ ATP molecules in optimal situation but there are various energy losses involved and the actual value is estimated to be 29-30. From $Joule = 6.84 \times 10^{18}$ eV and $mol = 6.02 \times 10^{23}$ and for $N = 38$ one would obtain the energy yield.86 eV per single ATP. The nominal value that I have used.5 eV. This is roughly 5 to 8 times higher than $E = ZeV, Z = 2$, which varies in the range.1-.16 eV so that the metabolic energy gain cannot be solely due to the electrostatic energy which would actually give only a small contribution.

In the thermodynamical approach to metabolism the additional contribution would be due to the difference of the chemical potential μ for cell exterior and interior, which is added to the membrane potential as effective potential energy. The discrepancy is however rather large and this forces the question the feasibility of the model. This forces to reconsider the model of osmosis in the light of Pollack's findings.

Pollack's findings in relation to osmosis and model for cell membrane and EEG

Osmosis (`http://tinyurl.com/yc5dbtzv`) has remained to me poorly understood phenomenon. Osmosis means that solvent molecules move through a semipermeable membrane to another side of the membrane if the concentration of solute is higher at that side. Solute can be water or more general liquid, supercritical liquid, and even gas.

Osmosis is not diffusion: it can occur also towards a higher concentration of water. Water molecules are not attracted by solute molecules. A force is required and the Wikipedia explanation is that solute molecules approaching pores from outside experience repulsion and gain momentum which is transferred to the water molecules.

The findings of Pollack inspire the question whether the formation of exclusion zone could relate to osmosis and be understood in terms of the fourth phase of water using genuine quantal description.

In the thermodynamical model for ionic concentrations one adds to the membrane resting potential a contribution from the difference of chemical potentials μ_i at the two sides of the membrane. Chemical potentials for the ions parametrize the properties of the cell membrane reducing basically to the properties of the channels and pumps (free diffusion and membrane potential do not entirely determine the outcome).

If the transfer of ions - now protons - through cell membrane is quantal process and through Josephson junctions defined by transmembrane proteins, then the thermodynamical model can at best be a phenomenological parameterization of the situation. One should find the quantum counterpart of thermodynamical description, and here the identification of quantum TGD as square root of thermodynamics in Zero Energy Ontology (ZEO) suggests itself. In this approach thermodynamical distributions are replaced by probability amplitudes at single particle level such that their moduli squared give Boltzmann weights.

1. Simplest Josephson junction model for cell membrane

The first guess is that quantum description is achieved by a generalization of the Josephson junction model allowing different values of Planck constant at magnetic flux tubes carrying dark matter.

1. Josephson junctions correspond microscopically to transmembrane proteins defining channels and pumps. In rougher description entire cell membrane is described as Josephson junction.

2. The magnetic field strength at flux tube can differ at the opposite side of the membrane and even the values of h_{eff} could in principle be different. The earlier modelling attempts

suggest that $h_{eff}/h = n = 2^k A$, where A is the atomic weight of ion, is a starting assumption deserving testing. This would mean that each ion resides at its own flux tubes.

The phase transitions changing the value of h_{eff} could induce ionic flows through cell membrane, say that occurring during nerve pulse since the energy difference defining the ratio of square roots of Boltzmann weights at the two sides of the membrane would change. Also the change of the local value of the magnetic field could do the same.

Consider first the simplest model taking into account only membrane potential.

1. The simplest model for Josephson junction defined by the transmembrane protein is as a two state system (Ψ_1, Ψ_2) obeying Schrödinger equation.

$$i\hbar_1 \frac{\partial \Psi_1}{\partial t} = ZeV\Psi_1 + k_1\Psi_2 \quad ,$$

$$i\hbar_2 \frac{\partial \Psi_2}{\partial t} = k_2\Psi_2 \quad .$$

One can use the decomposition $\Psi_i = R_i exp(i\Phi(t)$ to express the equations in a more concrete form. The basic condition is that the total probability defined as sum of moduli squared equals to one: $R_1^2 + R_2^2 = 1$. This is guaranteed if the hermiticity condition $k_1/\hbar_1 = \overline{k_2}\hbar_2$ holds true. Equations reduce to those for an ordinary Josephson junction except that the frequency for the oscillating Josephson current is scaled down by $1/h_{eff}$.

2. One can solve for R_2 assuming $\Phi_1 = eVt/\hbar_{eff}$. This gives

$$R_2(t) = sin(\Phi_0) + \frac{k_1}{\hbar_1} sin(\frac{eVt}{\hbar_1}) \quad .$$

R_2 oscillates around $sin(\Phi_0)$ and the concentration difference is coded by $\Phi 0$ taking the role of chemical potential as a phenomenological parameter.

3. The counterparts of Boltzmann weights would be apart from a phase factor square roots of ordinary Boltzmann weights defined by the exponent of Coulomb energy:

$$R = sin(\phi_0) = exp(\frac{ZeV(t)}{2T}) \quad .$$

Temperature would appear as a parameter in single particle wave function and the interpretation would be that thermodynamical distribution is replaced by its square root in quantum theory. In ZEO density matrix is replaced by its hermitian square root multiplied by density matrix.

2. The counterpart of chemical potential in TGD description

This model is not as such physically realistic since the counterpart of chemical potential is lacking. The most straightforward generalization of the thermodynamical model is obtained by the addition of an ion dependent chemical potential term to the membrane potential: $ZeV \rightarrow ZeV + \mu_I$. This would however require a concrete physical interpretation.

1. The most obvious possibility is that also the chemical potential actually correspond to an interaction energy - most naturally the cyclotron energy $E_c = \hbar_{eff} ZeB_{end}/m$ of ion - in this case proton - at the magnetic flux tube. Cyclotron energy is proportional to h_{eff} and can be rather large as assumed in the model for the effects of ELF em fields on brain.

2. This model would predict the dependence of the effective chemical potential on the mass and charge of ion for a fixed value of on h_{eff} and B_{end}. The scales of ionic chemical potential and ion concentrations would also depend on value of h_{eff}.

3. The model would provide a different interpretation for the energy scale of bio-photons, which is in visible range rather than infrared as suggested by the value of membrane potential.

   The earlier proposal [K41] was that cell membrane can be in near vacuum extremal configuration in which classical Z^0 field contributes to the membrane potential and gives a large contribution for ions. The problematic aspect of the model was the necessity to assume Weinberg angle in this phase to have much smaller value than usually. This difficulty could be perhaps avoided by noticing that the membrane potentials can differ for color receptors so that the earlier assignment of specific ions to color receptors could make sense for ordinary value of Weingerg angle. Second problem is that for proton the Z^0 contribution is negligible in good approximation so that this model does not explain the high value of the metabolic energy currency.

4. The simplest model the communications to magnetic body rely on Josephson radiation whose fundamental frequency f_J is at resonance identical with the cyclotron frequency $f_c(MB)$ at particular part of the flux tube of the magnetic body: $(f_c(MB) = f_J$. $f_c(MB)$ corresponds to EEG frequency in the case of brain and biophotons are produced from dark EEG photons as ordinary photons in phase transition reducing $h_{eff} = n \times h$ to h.

   In the modified model the sum $f_c + f_{J,n}$ $(f_{J,n} = E_J/n \times h)$ of h_{eff}-independent cyclotron frequency and Josephson frequency proportional to $1/h_{eff}$ equals to cyclotron frequency $f_c(MB)$ at "personal" magnetic body varying slowly along the flux tube: $f_c+f_{J,n} = f_c(MB)$. If also the variation of f_J assignable to the action potential is included, the total variation of membrane potential gives rise to a frequency band with width roughly

$$\frac{\Delta f}{f} \simeq \frac{2f_{J,n}}{f_c + f_{J,n}} = \frac{2f_{J,1}}{nf_c + f_{J,1}} \quad .$$

   If dark photons correspond to biophotons the energy is of cyclotron photon is in visible and UV range one has $nf_c = E_{bio}$ and

$$\frac{\Delta f}{f} \simeq \frac{2ZeV}{E_{bio} + ZeV} \quad .$$

   The prediction is scale invariant and same for all ions and also electron unless E_{bio} depends on ion. For $eV = .05$ eV, $Z = 1$, and $E_{bio} = 2$ eV ($f \simeq 5 \times 10^{14}$ Hz) one has $\Delta f/f \sim .1$ giving 10 per cent width for EEG bands assumed in the simpler model.

If this vision is on the correct track, the fundamental description of osmosis would be in terms of a phase transition to the fourth phase of water involving generation of dark matter transferred to the magnetic flux tubes. For instance, the swelling of cell by an in-flow of water in presence of higher concentration inside cell could be interpreted as a phase transition extending exclusion zone as a process accompanied by a phase transition increasing the value of h_{eff} so that the lengths of the flux tube portions inside the cell increase and the size of the exclusion zone increases. In general case the phase transitions changing h_{eff} and B_{end} by power of two factor are possible. This description should bring magnetic body as part of bio-chemistry and allow understanding of both equilibriumion distributions, generation of nerve pulse, and basic metabolic processes leading to the generation of ATP.

One can also model sensory receptors and try to understand the maximal sensitivity of color receptors to specific wavelengths in this framework. The new degrees of freedom make this task easy if one is only interested in reproducing these frequencies. More difficult challenge is to understand the color receptors from the first principles. It is also possible to combine the new view with the assumption that sensory receptor cells are near to vacuum extremals. This would add a cyclotron contribution to the generalized Josephson frequency depending only weakly on particle and being non-vanishing also for em neutral particles.

Why would charge separation generate large h_{eff}?

The basic question is whether and how the separation of electron and proton charges generates large h_{eff}? A possible mechanism emerged from a model [K98] explaining anomalously large gravimagnetic effect claimed by Tajmar *et al* [E8, E12] to explain the well-established anomaly related to the mass of Cooper pairs in rotating super-conduction. The mass is too large by fraction of order 10^{-4} and the proposal is that gravimagnetism changes slightly the effective Thomson magnetic field associated with the rotating super-conductor leading to wrong value of Cooper pairs mass when only ordinary Thomson field is assumed to be present. The needed gravimagnetic field is however gigantic: 28 orders larger than that predicted by GRT. Gravimagnetic field is proportional h_{eff}^2 in TGD and if one uses h_{gr} for electron-Earth system one obtains correct order of magnitude.

Nottale's finding that planetary orbits seem to correspond to Bohr orbits in gravitational potential with gigantic value of gravitational Planck constant is the basic input leading to the model of gravimagnetic anomaly.

1. By Equivalence Principle h_{gr} has the general form $h_{gr} = GMm/v_0$, where M and m are the interacting masses and v_0 is a parameter with dimensions of velocity. For 4 inner planets one has $v_0/c \simeq 2^{-11}$.

2. The notion of h_{gr} generalizes to that for other interactions. For instance, in electromagnetic case the formation of strong em fields implying charge separation leads to systems in which $h_{em} = Z_1 Z_2 e^2/v_0$ is large. Pollack's exclusion zone and its complement define this kind of systems and is identified as prebiotic life form.

3. Since the natural expansion parameter of perturbative expansion is the $g^2/4\pi\hbar$, one can say that transition to dark matter phase make the situation perturbative. Mother Nature is theoretician friendly.

h_{em} might be large in the exclusion zones (EZ) appearing in the water bounded by gel and their variants could play central role in living matter.

1. EZ carries very large negative charge with positive charge outside the exclusion zone.

2. TGD interpretation is in terms of $H_{1.5}O$ phase of water formed when every 4: th proton is transferred to magnetic body as dark particle with large value of h_{eff}. The proposal is that primitive life form is in question.

3. The pair formed by EZ and its complement could have large value of $h_{eff} = h_{em} = Z^2e^2/v_0$.

4. The velocity parameter v_0 should correspond to some natural rotation velocity. What comes in mind is that complement refers to Earth and v_0 is the rotation velocity at the surface of Earth. The prediction for h_{eff} would be of order $h_{em}/h = 4\pi\alpha Z^2 \times .645 \times 10^6 \simeq 5.9 \times 10^4 Z^2$.

5. Cell membrane involves also large charge separation due to very strong electric field over the cell membrane. Also now dark phases with large h_{em} or h_{gr} could be formed.

I have proposed that metabolic machinery generates large h_{eff} phase somehow. $h_{eff} = h_{em}$ hypothesis allows to develop this hypothesis in more detail.

1. I have speculated earlier [K50] that the rotating shaft of a molecular motor associated with ATP synthase plays a key role in generating dark matter phase. What comes in mind is that charge separation takes place associating exclusion zone with the shaft and the rotational velocity v_0 of the shaft appears in the formula for h_{em}. Of course, some numerical constant not far from unity could be present. The electric field over the mitochondrial membrane generates charge separation. One can imagine several identifications for the product of charges. The charge Z associated with the complement would be naturally associated with single dark flux tube containing dark nucleon consisting of dark protons. For instance, the charge associated with the exclusion zone could be the charge of the electronic Cooper pair giving $h_{em} = 2e \times Z/v_0$.

2. The value of v_0/c is expected to be of order 10^{-14} from the angular rotation rate of ADP synthase about few hundred revolutions per second. The order of magnitude for h_{em} could be same as for h_{gr} associated with Earth-particle system.

$h_{eff}(ATPsynthase) = h_{gr}(2e, Earth)$ would make possible reconnection of electromagnetic flux tubes with gravimagnetic flux tubes [K80].

Which came first: metabolism or cell membrane?

One of the basic questions of biology is whether metabolism preceded basic biopolymers or vice versa. RNA world scenario assumes that RNA and perhaps also genetic code was first.

1. The above view suggests that both approaches are correct to some degree in TGD Universe. Both metabolism and genetic code realized in terms of dark proton sequences would have emerged simultaneously and bio-chemistry self-organized around them. Dark proton sequences defining analogs of amino-acid sequences could have defined analogs of protein catalysts and played a key role in the evolution of the metabolic pathways from the primitive pathways involving only the phase transition between ordinary water and fourth phase of water.

2. There is very interesting article (see `http://tinyurl.com/ycdhd4fd`) [?]eporting that complex metabolic pathways are generated spontaneously in laboratory environments mimicking hot thermal vents. Glycolysis and pentose phosphate pathway were detected. The proposal is that these pathways are catalyzed by metals rather than protein catalysts.

3. In standard biology these findings would mean that these metabolic pathways emerged before basic biopolymers and that genetic code is not needed to code for the metabolic pathways during this period. In TGD framework dark genetic code [K44, L3] would be there, and could code for the dark pathways. Dark proton strings in one-one correspondence with the amino-acid sequences could be responsible for catalysts appearing in the pathways. Only later these catalysts would have transformed to their chemical counterparts and might be accompanied by their dark templates. One cannot even exclude the possibility that the chemical realization of the DNA-amino-acid correspondence involves its dark analog in an essential manner.

2.6.4 Could Pollack effect make cell membrane a self-loading battery?

The so called Clarendon dry pile is 175 years old battery still working. The current is very weak (nano Ampere) but the working of the battery is claimed to be not well-understood. The TGD inspired model for cold fusion leads to the proposal that Pollack effect is part of electrolysis. This inspires the idea that Pollack effect and possibly also the associated cold fusion could make Clarendon dry pile a self-loading battery. Cell membrane can be regarded as the analog of self-loading battery, and in TGD framework also as a generalised Josephson junction. Hence one can ask whether also cell membrane could be seen as a self-loading battery utilizing Pollack's mechanism. This would also allow to understand why hyperpolarization stabilizes the membrane potential and why depolarization generates nerve pulse.

Clarendon pile: 175 years old battery still working

Elemer Rosinger had a Facebook link to an article telling about Clarendon dry pile, a very long-lived battery providing energy for an electric clock (see `http://tinyurl.com/zeut69y`, `http://tinyurl.com/jhrww2a`, and `http://tinyurl.com/gvbrhra`). This clock known also as Oxford bell has been ringing for 175 years now and the article suggests that the longevity of the battery is not really understood. The bell is not actually ringing so loud that human ear could hear it but one can see the motion of the small metal sphere between the oppositely charged electrodes of the battery in the video.

The function principle of the clock is simple. The gravitational field of earth is also present. When the sphere touches the negative electrode, it receives a bunch of electrons and gives the bunch away as it touches positive electrode so that a current consisting of these bunches is running between electrons. The average current during the oscillation period of 2 seconds is nanoampere so that nanocoulomb of charge is transferred during each period (Coulomb corresponds to a 6.242×10^{18} elementary charges (electrons)).

The dry pile was discovered by priest and physicist Giuseppe Zamboni at 1812 (see `http://tinyurl.com/jkvtj6f`). The pile consists of 2,000 pairs of pairs of discs of tin foil glued to paper impregnated with Zinc sulphate and coated on the other side with manganese dioxide: 2,000 thin batteries in series. The operation of battery gradually leads to the oxidation of Zinc and the loss of magnase dioxide but the process takes place very slowly. One might actually wonder whether it takes place too slowly so that some other source of energy than the electrostatic energy of the battery would be keep the clock running. Karpen pile is analogous battery discover by Vasily Karpen (see `http://tinyurl.com/jpzcs32`). It has now worked for 50 years.

Cold fusion is associated with electrolysis. Could the functioning of this mystery clock involve cold fusion taken seriously even by American Physical Society thanks to the work of the group of prof. Holmlid. Electrolytes have of course been "understood" for aeons. Ionization leads to charge separation and current flows in the resulting voltage. With a feeling of deep shame I must confess that I cannot understand how the ionization is possible in standard physics. This of course might be just my immense stupidity - every second year physics student would immediately tell that this is "trivial" - so trivial that he would not even bother to explain why. The electric field between the electrodes is immensely weak in the scale of molecules. How can it induce the ionisation? Could ordinary electrolytes involve new physics involving cold fusion liberating energy? These are the questions which pop up in my stupid mind. Stubborn as I am in my delusions, I have proposed what this new physics might be with inspiration coming from strange experimental findings of Gerald Pollack, cold fusion, and my own view about dark matter has phases of ordinary matter with non-standard value $h_{eff} = n \times h$ of Planck constant. Continuing with my weird delusions I dare ask: Could cold fusion provide the energy for the "miracle" battery?

What batteries are?

To understand what might be involved one must first learn some basic concepts. I am trying to do the same.

1. Battery (see `http://tinyurl.com/8xqsnab`) consistes of two distinct electrochemical cells (see `http://tinyurl.com/jq8ljmo`). Cell consists of electrode and electrolyte. The electrodes are called anode and catode. By definition electron current along external wire flows to catode and leaves anode.

2. There are also ionic currents flowing inside the battery. In absence of the ionic currents the electrodes of the battery lose their charge. In the loading the electrodes get their charges. In the ideal situation the ionic current is same as electron current and the battery does not lose its charging. Chemical reactions are however taking place near and at the electrodes and in their reversals take place during charging. Chemical changes are not completely reversible so that the lifetime of the battery is finite.

   The ionic current can be rather complex: the carriers of the positive charge from anode can even change during the charge transfer: what matters that negative charge from catode is transferred to anode in some manner and this charge logistics can involve several steps. Near the catode the currents of positive ions (cations) and electrons from the anode combine to form neutral molecules. The negative current carriers from catode to the anode are called anions.

3. The charge of the clectrochemical cell is in the electrolyte near the surface of the electrode rather than inside it as one might first think and the chemical processes involve neutralization of ion and the transfer of neutral outcome to or from the electrode.

4. Catode - or better, the electrochemical cell containing the catode - can have both signs of charge. For positive charge one has a battery liberating energy as the electron current connecting the negative and positive poles goes through the load, such as LED. For negative charge current flows only if there is external energy feed: this is loading of the battery. External voltage source and thus energy is needed to drive the negative charges and positive charges to the electrodes. The chemical reactions involved can be rather complex and proceed in reverse direction during the loading process. Travel phone battery is a familiar example.

   During charging the roles of the anode and catode are changed: understanding this helps considerably.

Could dark cold fusion make possible self-loading batteries?

Could cold fusion help to understand why the Clarendon dry pile is so long lived?

1. The battery is series of very many simpler batteries. The mechanism should reduce to the level of single building brick. This is assumed in the following.

2. The charge of the battery tends to be reduced unless the ionic and electronic currents are identical. Also chemical changes occur. The mechanism involved should oppose the reduction of the charging by creating positive charge to the catode and negative charge to the anode or induce additional voltage between the electrodes of the battery inducing its loading. The energy feed involved might also change the direction of the basic chemical reactions as in the ordinary loading by raising the temperature at catode or anode.

3. Could be formation of Pollack's exclusion zones (EZs) in the elecrolytic cell containing the anode help to achieve this? EZs carry a high electronic charge. According to TGD based model protons are transformed to dark protons at magnetic flux tubes. If the positive dark charge at the flux tubes is transferred to the electrolytic cell containing catode and transformed to ordinary charge, it would increase the positive charge of the catode. The effect would be analogous to the loading of battery. The energy liberated in the process would compensate for the loss of charge energy due to electronic and ionic currents.

4. In the ordinary loading of the battery the voltage between batteries induces the reversal of the chemical processes occurring in the battery. This is due to the external energy feed. Could the energy feed from dark cold fusion induce similar effects now? For instance, could the energy liberated at the catode as positively charged dark nuclei transform to ordinary ones raise the temperature and in this manner feed the energy needed to change the direction of the chemical reactions.

Cell membrane as self-loading battery and how nerve pulse is generated?

This model might have an interesting application to the physics of cell membrane.

1. Cell membrane consisting of two lipid layers defines the analog of a battery. Cell interior plus inner lipid layer (anode) and cell exterior plus outer lipid layer (catode) are analogs of electrolyte cells.

   What has been troubling me for two decades is how this battery manages to load itself. Metabolic energy is certainly needed and ADP-ATP mechanism is essential element. I do not however understand how the membrane manages to keep its voltage.

   Second mystery is why it is hyperpolarization rather than polarization, which tends to stabilize the membrane potential in the sense that the probability for the spontaneous generation of nerve pulse is reduced. Neither do I understand why depolarization (reduction of the membrane voltage) leads to a generation of nerve pulse involving rapid change of the sign of the membrane voltage and the flow of various ionic currents between the interior and exterior of the cell.

2. In the TGD inspired model for nerve pulse cell interior and cell exterior or at least their regions near to lipid layers are regarded as super-conductors forming a generalized Josephson junction. For the ordinary Josephson junction the Coulombic energy due to the membrane voltage defines Josephson energy. Now Josephson energy is replaced by the ordinary Josephson energy plus the difference of cyclotron energies of the ion at the two sides of the membrane. Also ordinary Josephson radiation can be generated. The Josephson currents are assumed to run along magnetic flux tubes connecting cell interior and exterior. This assumption receives support from the strange finding that the small quantal currents associated with the membrane remain essentially the same when the membrane is replaced with polymer membrane.

3. The model for Clarendon dry pile suggests an explanation for the self-loading ability. The electrolytic cell containing the anode corresponds to the negatively charged cell interior,

where Pollack's EZs would be generated spontaneously and the feed of protonic charge to the outside of the membrane would be along flux tubes as dark protons to minimize dissipation. Also ions would flow along them. The dark protons driven to the outside of the membrane transform to ordinary ones or remain dark and flow spontaneously back and provide the energy needed to add phosphate to ADP to get ATP.

4. The system could be quantum critical in the sense that a small reduction of the membrane potential induces nerve pulse. Why the ability to generate Pollack's EZs in the interior would be lost for a few milliseconds during nerve pulse? The hint comes from the fact that Pollack's EZs can be generated by feeding infrared radiation to a water bounded by gel. Also the ordinary Josephson radiation generated by cell membrane Josephson junction has energy in infrared range!

   Could the ordinary Josephson radiation generate EZs by inducing the ionization of almost ionized hydrogen bonded pairs of water molecules. The hydrogen bonded pairs must be very near to the ionization energy so that ordinary Josephson energy of about .06 eV assignable to the membrane voltage is enough to induce the ionization followed by the formation of $H_{3/2}O$. The resulting EZ would consist of layers with the effective stoichiometry $H_{3/2}O$.

   As the membrane voltage is reduced, Josephson energy would not be anymore enough to induce the ionization of hydrogen bonded pair of water molecules, EZs are not generated, and the battery voltage is rapidly reduced: nerve pulse is created. In the case of hyperpolarization the energy excees the energy needed for ionization and the situation becomes more stable.

5. This model could also allow to understand the effect of anesthetes [K78] [L22]. Anesthetes could basically induce hyperpolarization so that Josephson photons would continually generate Pollack's EZ:s and creating of dark particles at the magnetic flux tubes. This need not mean that consciousness is lost at the cell level. Only sensory and motor actions are prevented because nerve pulses are not possible. This prevents formation of sensory and motor mental images at our level of hierarchy.

   Meyer-Overton correlation states that the effectiveness of the anesthete correlates with its solubility to the lipid membrane. This is the case if the presence of anesthete in the membrane induces hyperpolarization so that the energies of the photons of Josephson radiation would be higher than needed for the generation of EZs accompanied by magnetic flux tubes along which ionic Josephson currents would flow between cell interior and exterior. For these quantal currents evidence exists [K82]. In the case of battery these dark ions would flow from the cell containing anode to that containing catode. For depolarization the energy of Josephson photons would be too low to allow the kicking off protons from hydrogen bonded pairs of water molecules so that EZs would not be created and self-loading would stop and nerve pulse would be generated.

2.7 Could Photosensitive Emulsions Make Dark Matter Visible?

The article "Possible detection of tachyon monopoles in photographic emulsions" by Keith Fredericks [H18] describes in detail (`http://tinyurl.com/ybjk94f9`) very interesting observations by him and also by many other researchers about strange tracks in photographic emulsions induced by various (probably) non-biological mechanisms and also by the exposure to human hands (touching by fingertips) as in the experiments of Fredericks. That the photographic emulsion itself consists of organic matter (say gelatin) might be of significance.

2.7.1 The Findings

The tracks have width between 5 μm-110 μm (horizontal) and 5 μm-460 μm (vertical). Even tracks of length up to at least 6.9 cm have been found. Tracks begin at some point and end abruptly. A given track can have both random and almost linear portions, regular periodic structures (figs 11 and 12), tracks can appear in swarms (**Fig.** 24), bundles (**Fig.** 25), and correlated pairs (**Fig.**

16), tracks can also split and recombine (**Fig.** 32) (here and below "**Fig.**" refers to a figure of the article at `http://tinyurl.com/ybjk94f9`).

Tracks differ from tracks of known particles: the constant width of track implies that electrons are not in question. No delta rays (fast electrons caused by secondary ionization appearing as branches in the track) characteristic for ions are present. Unlike alpha particle tracks the tracks are not straight. In magnetic fields tracks have parabolic portions whereas ordinary charged particle move along spiral. The magnetic field needed to cause spiral structure for baryons should be by two orders of magnitude higher than in the experiments.

For particle physicist all these features - for instance constant width - strongly suggest pre-existing structures becoming visible for some reason. The pre-existing structure could of course correspond to something completely standard structures present in the emulsion. If one is ready to accept that biology involves new physics, it could be something more interesting.

Also evidence for cold fusion is reported by the group of Urutskoev [H11]. There is evidence for cold fusion in living matter [C6, C22]: the fact that the emulsion contains gelatin might relate to this. In [L3] a dark matter based mechanism of cold fusion allowing protons to overcome the Coulomb wall is discussed. Either dark protons or dark nuclei with much larger quantum size than usually would make this possible and protons could end up to the dark nuclei along dark flux tubes. In TGD inspired biology dark protons (large h_{eff}) with scaled up Compton length of order atomic size are proposed to play key role since their states allow interpretation in terms of vertebrate genetic code [L3, K25].

2.7.2 The Importance Of Belief System

These structures could be something quite standard or not. This readiness to consider non-standard explanations depends on belief system.

1. In the belief system of standard physics these pre-existing structures would be organic material consisting of ordinary matter so that no new physics is involved. Probably it is easy to kill this hypothesis. If this can be done, the situation becomes really interesting.

2. In my own belief system they *could* correspond to dark matter structures made visible by some mechanism. The presence of human hands could induce this phenomenon in the experiments of Fredericks. If so we might be already considering remote interactions involving dark photons and magnetic flux tubes, whose images "tracks" would be.

3. The first guess is that these structures are in the emulsion. This need not be the case! They could be structures outside- say in human hands - sending dark photon beam absorbed by the small photosensitive crystals in the emulsion. A photograph of dark matter (say in the hands of sender) would be formed! One possibility is that tracks represent a photograph of the dark matter at the flux tubes of the magnetic body of the emulsion. This would be a variant for what Gariaev perhaps managed to achieve with camera: taking a photo of dark matter [K1] !

4. Unfortunately belief system becomes important also in second manner. The reductionistic belief system tells that the tracks must be something trivial. There cannot be new physics in scale of cell as we have read in text books. Therefore these tracks are not studied by professionals who could very easily find whether there is something really interesting involved.

Dark matter in TGD based belief system corresponds to a hierarchy of phases of ordinary matter with an effective value h_{eff} of Planck constant coming as integer multiple of ordinary Planck constant. This makes possible macroscopic quantum phases consisting of dark matter. The flux tubes could carry magnetic monopole flux but the magnetic charge would be topological (made possible by the non-trivial second homology of CP_2 factor of the 8-D embedding space containing space-times as surfaces) rather than Dirac type magnetic charge.

The TGD inspired identification of tracks could be as images of magnetic flux tubes or bundles of them containing dark matter defining one of the basic new physics elements in TGD based quantum biology. One can imagine two options for the identification of the tracks as "tracks".

1. The primary structures are in the photo-sensive emulsion.

2. The structures in photograph are photographs of dark matter in external world, say structures in human hands or human body or of dark matter at some magnetic body, say at the flux tubes of the magnetic body of the emulsion.

The fact that the tracks have been observed in experimental arrangements not involving exposure to human hands, indeed suggests that tracks represent photographs about parts of the magnetic body assignable to the emulsion. For this option the external source would serve only as the source of possibly dark photons.

This would imply a close analogy with the experiments of Peter Gariaev's group interpreted in TGD framework as photographing of the magnetic body of DNA sample [K1]. Also here one has an external source of light: the light would be transformed to dark photons in DNA sample, scatter from the dark charged particles at the flux tubes of the magnetic body of DNA sample, and return back transforming to ordinary light and generating the image in the photosensitive emulsion.

2.7.3 Why Not Tachyonic Monopoles?

The identification of the tracks as orbits of particles proposed by author and also by other experimentalists is to my opinion problematic for the reasons which I have already explained. The article of Fredericks lists further details which do not conform with the particle interpretation. A further proposal is that the particles are tachyonic magnetic monopoles. One motivation for the monopole hypothesis is the (unsuccessful) attempt to explain the parabolic shape of the tracks in external magnetic field.

To my view the interpretation as a tachyonic monopole - a notion introduced by Recami and Mignani [H26] (`http://tinyurl.com/yajz68tt`) - adopted in the article is theoretically problematic. Of course, if the tracks are actually pre-existing structures made visible by some mechanism, there is no need to postulate super-luminal propagation. To see the problem, one can start from a general formula relating energy, momentum and mass. One has

$$E^2 = p^2 + m^2 \quad . \tag{2.7.1}$$

When m is imaginary as for tachyon so that one can write $m = iM$, one obtains

$$E^2 = p^2 - M^2 \quad . \tag{2.7.2}$$

If E and p are assumed to be real as is done usually the condition $E \geq 0$ and more generally the reality of E gives $p \geq M$. Tachyon cannot therefore be at rest and one cannot assign to it kinetic energy since tachyon at rest would have imaginary energy.

This has two implications.

1. The identification as tachyon and the conclusion $p \ll M$ from experiments (see figure 34 for the relation between E, p and m in various cases) is not consistent with $p \geq M$.

2. Recami and Mignani assign a kinetic energy to tachyon (formula 14). Unfortunately, this formula does not make sense if one accepts that E and p are real since one cannot assign to tachyon kinetic energy: the analogy of kinetic energy would be "kinetic momentum" defined as the difference of the actual momentum and minimal momentum $p = M$ ($p_{kin} = \sqrt{E^2 + M^2} - M \simeq E - M - M^2/2E$). As Fredericks notices, the behavior is not actually consistent with a motion of magnetic monopole in magnetic field. Parabolic orbits are in plane orthogonal to magnetic field rather than containing its direction vector (`http://tinyurl.com/ybjk94f9`)!

2.7.4 Interpretation As Dark Matter Structures Becoming Visible In Presence Of Living Matter

As such the observations are extremely interesting. I cannot however believe that the tracks represent particles. To my opinion tachyonic monopole interpretation fails because it does not make sense to talk about kinetic energy of tachyon.

To me the complex structures of tracks very strongly suggest pre-existing structures becoming visible for some reason. Looking the shape of tracks brings to my mind linear structure such as protein molecules. They contain regular helical portions and denatured portions. Now the longitudinal scale is of course much longer. The transversal scale is that for cells. This is perhaps not too surprising since organic materials such as gelatin are involved. The flux tubes could carry magnetic monopole fluxes and in purely formal sense would thus be analogous to magnetic monopoles with space-like momentum in their direction - that is tachyonic monopoles. They would be however actually ordinary systems with non-tachyonic momentum.

The particles possibly causing the tracks cannot be electrically charged since in this case they would not have managed to reach the emulsion. There seems however to be an interaction with magnetic fields since the tracks are parabola. Urutskoev *et al* [H11] propose that tracks are caused by magnetic monopoles. Unfortunately, the predicted parabolic orbit would be in the plane containing the magnetic field lines: the situation is completely analogous to the parabolic motion of projectile in the Earth's gravitational field.

"Tracks" as photographs of magnetic flux tubes?

Consider first the identification of "tracks" (for convenience I will drop the quotation marks in the sequel) as images of magnetic flux tubes.

1. The hypothesis that tracks are photographs of flux tubes explains the "track-ness". In the Earth's magnetic field the thickness of flux tubes is by flux quantization of the same order of magnitude as the thickness of thickest tracks observed for single flux quantum. Flux tube hypothesis seems to be also consistent with the other strange properties of the "tracks". In particular, the composition to random and smoothly curved portion would conform with the idea that also linear molecules are formed around templates defined by magnetic flux tubes.

2. The tracks have been observed to be created in several situations and it is not at all clear whether the exposure to hands in the experiments of Fredericks is absolutely necessary. TGD suggests that the analog of dielectric breakdown associated with nerve pulses (the electric field at cell membrane is two times higher than the electric field inducing di-electric breakdown in air) replaces the strong electric fields causing di-electric breakdown used in the experiments of Urutskoev [H11]. Dark magnetic flux tubes can accompany any kind of matter so that tracks could be also images about the dark magnetic body of an external object rather than that of emulsion. In principle, one cannot exclude the possibility that the presence of the experimenter is decisive in all cases. If so, this would be a new kind of experimenter effect.

3. To what could the abrupt ending of the track correspond in this picture? Magnetic flux tubes cannot end but they can go to another space-time sheet through wormhole contact and apparently disappear. This would indeed take place for the closed flux tubes representing elementary particles and carrying magnetic monopole flux. The flux tubes could quite generally carry a multiple of magnetic monopole flux. They would have rather large scale as compared to the CP_2 scale of 10^4 Planck lengths.

1. Explanation for parabolic portions of tracks

The presence of parabolic tracks in the plane orthogonal to the external static magnetic fields is very interesting feature to be explained. Parabolic character could be simply due to the simplest non-linear fit to the shape of the flux tube: it is however argued that parabolic character is exact. One should understand why the flux tube is orthogonal to the external magnetic field or magnetic field generated by the emulsion? Could this reflect the geometry of the experimental arrangement?

In TGD framework one can consider a very natural possibility that a constant electric field orthogonal to the external magnetic field is present.

1. In standard physics the presence of the electric field might be excluded easily. In TGD framework simplest space-time sheets representing constant Kähler magnetic fields allow a simple deformation to sheets containing orthogonal electric field. A simple situation (not

necessarily a preferred extremal of Kähler action) corresponds to a space-time sheet $X^4 \subset M^4 \times S^2$, S^2 a geodesic sphere of CP_2. Using spherical coordinates $(u = cos(\Theta), \Phi)$ for S^2 and Cartesian coordinates (t, z, x, y) for M^4, one has $(u = f(x), \Phi = \omega t + ky)$ $(c = 1)$. The non-vanishing components of magnetic and electric fields are apart from a coefficient of proportionality of order unity given by $E_x \equiv J_{0x} = \partial_x u \times \omega$ and $B^z \equiv J_{xy} = \partial_x u \times k$ with $E_x/B_z = \omega/k$. Electric and magnetic fields are orthogonal and the value of the ω/k ratio fixes the electric field strength in terms of the magnetic field strength. In fact, the mere assumption that the CP_2 projection is 2-dimensional implies that electric and magnetic parts of various induced gauge fields are orthogonal.

2. This field would be represented by a space-time sheet at which the flux tubes of the external magnetic are topologically condensed (glued by wormhole contacts). The charged particles inside the flux tube would experience the presence of this electric field as a constant force trying to force them out from the flux tube. If the flux tube adopts a parabolic shape of the orbit of individual charged particle, the electric force is parallel to the flux tube and one has equilibrium situation. *All* charged particles inside flux tube must move with the same velocity at given point of flux tube: this conforms with super-conductivity implying the existence of global order parameter. Note that the dark charged particles inside flux tube would not directly interact with the emulsion or with air so that they can reach the emulsion easily.

3. For non-relativistic motion the equation for the parabolic orbit is $y = x^2/L$, where the length $L = 2mv^2/qE$ characterizes the size scale of the parabola. Parametrizing E in terms of voltage and length L as $E = V_e/L$ one has $eV_c/mc^2 = 2(v/c)^2$. For electron rest energy $m_e c^2 = .5$ MeV and $v/c = 10^{-3}$ one would have $V_c = 1$ V. For proton the electric field would be by a factor 2^{11} stronger for the same orbit parameters.

   For a given electric field the parameters of the parabola allow to distinguish between flux tubes carrying different charged particles since the kinetic energies from the are expected to be different. I have indeed proposed that magnetic flux tubes could serve as a kind of filter allowing to distill ions with different masses at their own magnetic flux tubes: the equilibrium condition would make the flux tubes filters. The cyclotron energy scale $E_c = \hbar_{eff} ZeB/m$ would give a rough guess for the order of magnitude of kinetic energy of the particle: cyclotron energy scale is proportional to h_{eff} so that quite high energies can be considered. eV as a typical atomic energy scale and also as the energy scale of bio-photons (interpreted as decay products of dark photons [K15]) is the first guess for the energy scale.

4. It should be easy to check whether the emulsion is accompanied by electric field and also to deduce bounds for its values. Living matter is electret and one could imagine that gelatin contains some kind of remnants of bio-electric fields - perhaps as dark variants.

2. The decrease of the track thickness with the increase of distance

Urutskoev *et al* [H11] have reported the decrease of the track thickness with the increase of the source distance. Does this mean that the flux tubes photographed are near the source and the reduction of track thickness with distance is an optical effect similar to that for ordinary photographs?

If the flux tubes belong to the magnetic body of emulsion, this explanation fails. It is however easy to invent plausible explanation also in this case. based on a simple model for the quantization of the magnetic flux.

1. The reconnection for flux tubes of the source and emulsion can take place only for flux tubes with same magnetic field strength and by flux conservation same transversal area S. Note that conservation of magnetic flux implies $B \times S = constant$ so that increasing the thickness of flux tube decreases the strength of the magnetic field.

2. If the flux tubes have a fractal structure with flux tubes containing bundles of flux tubes (bundle structure has been observed for the tracks), one can argue that the weaker the magnetic field, the smaller the number of flux tubes in the typical bundle and the smaller

the radius of the bundle if the flux tubes inside bundle have constant density. For dipole field the weakening of the average field with distance could mean that flux tube bundles split to smaller bundles. A "temporary" splitting of at track to a bundle of widely separated tracks has been observed for tracks and would mean reduction of the average magnetic field strength.

3. If the number of grains corresponds to the number of flux tubes within a bundle, the number of flux tubes in the bundle would be thousands. The average size of the grain suggests a diameter of order .34 μ m for the flux tubes. If the magnetic length $L_B = \sqrt{h/eB}$ equals to $L_B = .17$ μm (scaling rule: 1 Tesla corresponds to $L_B = 64$ nm), the magnetic field strength would be 354 Gauss (the Earth's magnetic field has nominal value of.5 Gauss). The external magnetic field of 20 Gauss used by Urutskoev *et al* defines a good candidate for the flux tube radius. For this field single flux tube would correspond to 18-19 crystals.

If this model is on correct track, these photographs could among other things provide means for the detailed study of the quantized dynamics of magnetic fields based on decomposition to flux tubes consisting of flux tubes consisting of...

What could be the source of dark photons?

Photographic emulsion would work as usually by detecting photons. What is clear that the photons must be dark when they scatter from the magnetic flux tubes of the magnetic body of the emulsion. There are however several options for how the dark photons are produced.

1. Ordinary photons from the source could hit the emulsion, transform to dark photons and propagate to the magnetic flux tubes, reflect back, transform to ordinary photons, and interact with the micro-crystals of the emulsion and generate the visible track as the image of the flux tube. Emulsion would take the role possessed by DNA sample in Gariaev's experiments and the external source would take the role of lamps used to generate visible light [K1].

2. Dark photons could also originate from the source. They could arrive along the flux tubes of its magnetic body. In the experimental situations considered these would reconnect with the flux tubes of the magnetic body of the emulsion and scatter from dark matter at them. After this the photons would propagate to the emulsion and transform to ordinary photons and give rise to the image. Reconnection of the flux tubes is the basic mechanism of attention in TGD inspired theory of consciousness and in TGD inspired biology, and also used to explain various findings of Persinger *et al* [K25].

3. The emission of dark photons is expected to take place in critical systems in which large values of effective Planck constant h_{eff} making possible long range correlations can be present. The situations studied (glow discharge plasma processes, exploding wires and foils, low energy discharges in water, super-compression of solid targets using electron beams) indeed seem to be critical. Only the search of monopoles of solar origin at the north pole represents a situation in which criticality is not present in obvious manner (the measurement method might involve criticality to guarantee maximal sensitivity). This kind of situations would generate time varying magnetic fields, whose flux tubes could reconnect with the magnetic flux tubes assignable to the photographic emulsion. This in turn would make possible for dark photons to propagate from source to the emulsion. In some experiments also static magnetic fields are present.

4. What is interesting that the "cold currents" reported already by Tesla in his experiments involving di-electric breakdowns at surfaces of wires of coils could correspond to dark currents propagating along the magnetic flux tubes [L11] [L11]. Most of these experiments correspond to critical situations making possible the manifestation of otherwise hidden new physics. Whether one can see these manifestations of course depends on whether one believes on the reductionistic Bible or not.

Chapter 3

About the New Physics Behind Qualia

3.1 Introduction

As the title expresses, this chapter was originally about the new physics behind qualia. The model of qualia indeed involves a lot of new physics: many-sheeted space-time; massless extremals; magnetic and cyclotron phase transitions associated with quantum critical quantum spin glass phases of exotic super conductors at cellular space-time sheets; classical color and electro-weak gauge fields in macroscopic length scales, to name the most important ingredients. Gradually the chapter however expanded so that it touches practically all new physics possibly relevant to TGD inspired quantum biology. Various physical mechanisms are discussed in exploratory spirit rather than restricting the consideration to those ideas which seem to be the final word about quantum biology or qualia just at this moment.

3.1.1 Living Matter And Dark Matter

Dark matter is identified as a macroscopic quantum phase with large $\hbar$. Also living matter would involve in in an essential way matter with a large value of $\hbar$ and hence dark, and form conformally confined (in the sense that the net conformal weight of the state is real) blobs behaving like single units with extremely quantal properties, including free will and intentional action in time scales familiar to us. Dark matter would be responsible for the mysterious vital force.

Any system for which some interaction becomes so strong that perturbation theory does not work, gives rise to this kind of system in a phase transition in which $\hbar$ increases to not lose perturbativity gives rise to this kind of "super-quantal" matter. In this sense emergence corresponds to strong coupling. One must however remember that emergence is actually much more and involves the notion of quantum jump. Dark matter made possible by dynamical $\hbar$ is necessary for macroscopic and macro-temporal quantum coherence and is thus prerequisite for emergence.

Physically large $\hbar$ means a larger unit for quantum numbers and this requires that single particle states form larger particle like units. This kind of collective states with weak mutual interactions are of course very natural in strongly interacting systems. Quantum jumps integrate effectively to single quantum jump and longer moments of consciousness result. Entire hierarchy of size scales is predicted corresponding to values of h_{eff} coming as integer multiples of ordinary Planck constant: $h_{eff} = n \times h$ [K118, B19]. The larger the value of h_{eff} the longer the characteristic time scale of consciousness and of a typical life cycle.

It is now possible to deduce $h_{eff} = n \times h$ hierarchy from the non-determinism of Kähler action giving rise to quantum criticality characterized by integer n. Quantum criticality is realized in terms of conformal deformations of the light-like 3-surfaces defining parton orbits and preserving their light-likeness. Also super-symplectic algebra of the boundary of CD has conformal structure as well as the conformal algebra of light-cone boundary. These transformations act as gauge symmetries, and there are n conformal equivalence classes for space-time sheets connecting same space-like 3-surfaces at the ends of causal diamond. Negentropic entanglement can be assigned with this degeneracy. The gauge algebra is sub-algebra of full conformal algebra with generators having conformal weights, which are multiples of n.

The notion of field body means that dark matter at the magnetic flux tubes would serve as an intentional agent using biological body as a motor instrument and sensory receptor. Dark matter would be the miraculous substance that living systems are fighting for, and perhaps the most important substance in metabolic cycle.

3.1.2 Macroscopic Quantum Phases In Many-Sheeted Space-Time

The crucial empirical ingredient turned out to be the observations about the effects of oscillating ELF electromagnetic fields on central nervous system, endocrine system and immune system made after sixties [J34, J35]. The largest effects are obtained at odd multiples of cyclotron frequencies of various biologically important ions like Ca_{++} in Earth's magnetic field. Also amplitude modulation of RF and MW fields by these frequencies has effects. This leads to a surprising conclusion in violent conflict with standard physics view about world. Magnetically confined states of ions in Earth's magnetic field having minimal size of order cell size and energy scale of order 10^{-14} eV would be in question if ordinary quantum theory would be the final word. Dark matter hierarchy with the spectrum of Planck constants given by $\hbar = r\hbar_0$ with the favore values or r given by ruler and compass hypothesis or by Mersenne hypothesis, resolves the paradox [K37].Note that the hypothesis is $h_{eff} = nh$, where n is product of distinct Fermat primes and power 2^{k_d}. For $k_d = 41$ level of the dark matter hierarchy the energies $E = \hbar\omega$ of ELF photons are above thermal threshold for $f \geq 1$ Hz.

The notion of many-sheeted ionic equilibrium brings in in the mechanism with which supra-currents at the magnetic flux tubes control the matter at atomic space-time sheets. The strange anomalies challenging the notions of ionic channels and pumps [I63] provide support for the resulting general vision.

3.1.3 Mind Like Space-Time Sheets As Massless Extremals

Mind like space-time sheets are the geometric correlates of selves. So called massless extremals (MEs) [K70] provide ideal and unique candidates for mind like space-time sheets. MEs give rise to hologram like cognitive representations. The assumption that they serve as Josephson junctions allows to understand the amplitude windows associated with the interaction of ELF em fields with brain tissue. The properties of MEs inspire the hypothesis that they give rise to an infinite hierarchy of electromagnetic life forms living in symbiosis with each other and bio-matter. EEG can be interpreted as associated with ELF MEs which is one important level in this hierarchy responsible for the cultural aspects of consciousness.

Our mental images propagating in neural circuits should correspond to microwave (MW) MEs with wavelengths below .3 meters. The communications between quantum antennae associated with ELF and RF MEs provides an elegant model for the formation and recall of long term memories and realize hologrammic cognitive representations. Self hierarchy has as a particular dynamical correlate the hierarchy of Josephson currents modulated by Josephson currents modulated by... having magnetic transition frequencies as their basic frequencies. Josephson currents flow along join along boundaries bonds connecting space-time sheets belonging at various levels of the hierarchy ("biofeedback").

3.1.4 Classical Color And Electro-Weak Fields In Macroscopic Length Scales

One can say that the basic physics of standard model without symmetry breaking and color magnetic confinement is realized at classical level on cellular space-time sheets. Classical Z^0 fields, W fields and gluon fields unavoidably accompany non-orthogonal electric and magnetic fields. The proper interpretation of this prediction is in terms of a p-adic and dark fractal hierarchies of standard model physics with scaled down mass scales making possible long range weak and color interactions in arbitrarily long length scales.

This prediction forces to modify even the model of nuclei [K97]. Nucleons carry exotic color and form nuclear strings consisting of color bonds with exotic quark q and antiquark $\overline{q}$ at their ends. These exotic quarks correspond to $k = 127$ level of dark matter hierarchy. Also dark variants of ordinary quarks with size of about atom are possible. It is also possible to have $u\overline{d}$ and $\overline{u}d$ type color bonds which carry em and weak charge and this means exotic nuclear ionization. Tetraneutron [C12, C3] would represent one particular example of this kind of exotically ionized nucleus [K97]. Exotic nuclear physics would have also implications for the ordinary condensed matter physics and could be involved with the very low compressibility of liquid phase and the anomalous behavior of water [K38].

Exotic ionization is the key element in the quantum model for the control action of the magnetic body on biological body. Exotic ionization induces dark plasma oscillations which in turn generate via classical em fields ordinary ohmic currents at the level of the ordinary matter. Nerve pulse patterns [K82] and Ca^{2+} waves [K44, K49] would represent examples of physiological correlates of this quantum control.

3.1.5 Mersenne Hypothesis

The generalization of the embedding space means a book like structure for which the pages are products of singular coverings or factor spaces of CD (causal diamond defined as intersection of future and past directed light-cones) and of CP_2 [K40]. This predicts that Planck constants are rationals and that given value of Planck constant corresponds to an infinite number of different pages of the Big Book, which might be seen as a drawback. If only singular covering spaces are allowed the values of Planck constant are products of integers and given value of Planck constant corresponds to a finite number of pages given by the number of decompositions of the integer to two different integers.

TGD inspired quantum biology and number theoretical considerations suggest preferred values for $r = \hbar/\hbar_0$. For the most general option the values of $\hbar$ are products and ratios of two integers n_a and n_b. Ruler and compass integers defined by the products of distinct Fermat primes and power of two are number theoretically favored values for these integers because the phases $exp(i2\pi/n_i)$, $i \in \{a, b\}$, in this case are number theoretically very simple and should have emerged first in the number theoretical evolution via algebraic extensions of p-adics and of rationals. p-Adic length scale hypothesis favors powers of two as values of r.

One can however ask whether a more precise characterization of preferred Mersennes could exist and whether there could exists a stronger correlation between hierarchies of p-adic length scales and Planck constants. Mersenne primes $M_k = 2^k - 1$, $k \in \{89, 107, 127\}$, and Gaussian Mersennes $M_{G,k} = (1+i)k-1$, $k \in \{113, 151, 157, 163, 167, 239, 241..\}$ are expected to be physically highly interesting and up to $k = 127$ indeed correspond to elementary particles. The number theoretical miracle is that all the four scaled up electron Compton lengths with $k \in \{151, 157, 163, 167\}$ are in the biologically highly interesting range 10 nm-2.5 μm). The question has been whether these define scaled up copies of electro-weak and QCD type physics with ordinary value of $\hbar$. The proposal that this is the case and that these physics are in a well-defined sense induced by the dark scaled up variants of corresponding lower level physics leads to a prediction for the preferred values of $r = 2^{k_d}$, $k_d = k_i - k_j$.

What induction means is that dark variant of exotic nuclear physics induces exotic physics with ordinary value of Planck constant in the new scale in a resonant manner: dark gauge bosons transform to their ordinary variants with the same Compton length. This transformation is natural since in length scales below the Compton length the gauge bosons behave as massless and free particles. As a consequence, lighter variants of weak bosons emerge and QCD confinement scale becomes longer.

This proposal will be referred to as Mersenne hypothesis. It leads to strong predictions about EEG [K37] since it predicts a spectrum of preferred Josephson frequencies for a given value of membrane potential and also assigns to a given value of $\hbar$ a fixed size scale having interpretation as the size scale of the body part or magnetic body. Also a vision about evolution of life emerges. Mersenne hypothesis is especially interesting as far as new physics in condensed matter length scales is considered: this includes exotic scaled up variants of the ordinary nuclear physics and their dark variants. Even dark nucleons are possible and this gives justification for the model of dark nucleons predicting the counterparts of DNA, RNA, tRNA, and amino-acids as well as realization of vertebrate genetic code [K115].

These exotic nuclear physics with ordinary value of Planck constant could correspond to ground states that are almost vacuum extremals corresponding to homologically trivial geodesic sphere of CP_2 near criticality to a phase transition changing Planck constant. Ordinary nuclear physics would correspond to homologically non-trivial geodesic sphere and far from vacuum extremal property. For vacuum extremals of this kind classical Z^0 field proportional to electromagnetic field is present and this modifies dramatically the view about cell membrane as Josephson junction. The model for cell membrane as almost vacuum extremal indeed led to a quantitative breakthrough in TGD inspired model of EEG and is therefore something to be taken seriously. The safest option concerning empirical facts is that the copies of electro-weak and color physics with ordinary value of Planck constant are possible only for almost vacuum extremals - that is at criticality against phase transition changing Planck constant.

3.1.6 P-Adic-To-Real Transitions As Transformation Of Intentions To Actions

Hearing and cognition are very closely relatedone could even argue that we think using language. The view that p-adic physics is physics of intention and cognition leads to the vision that the transformation of thoughts to actions and sensory inputs to thoughts correspond to real–p-adic phase transitions for space-time sheets. For a long time the question how p-adic space-time sheets relate to the real ones lacked a precise answer, and therefore also the question what the transformation of p-adic space-time sheet to real ones really means. The advances in the understanding the precise relationship between p-adic and real space-time sheets discussed in [K100] led however to a definite progress in this respect [K67].

The transformation of p-adic space-time sheets to real ones must respect the conservation of quantum numbers: this requires that the real system either receives or sends energy when the p-adic-to-real transitions realizing the intention occurs. If p-adic ME is transformed to a negative energy ME in the process, real system must make a transition to a higher energy state. This kind of transitions cannot occur spontaneously so that the outcome is a precisely targeted realization of intention. The additional bonus is that buy now-let others pay mechanism makes possible extreme flexibility. There are reasons to expect that the energies involves cannot be too high however.

The model of intentional action as a quantum transition for which the probabilities for various intention-action pairs should in principle be deducible from S-matrix is discussed in [K100] using the vision about physics as a generalized number theory as a guide line. This model leads to fresh insights about the construction of the ordinary S-matrix and essentially the same kind of general expressions for S-matrix elements result as in the case of ordinary scattering.

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` [L13].

3.2 Updated View About The Hierarchy Of Planck Constants

The original hypothesis was that the hierarchy of Planck constants is real. In this formulation the embedding space was replaced with its covering space assumed to decompose to a Cartesian product of singular finite-sheeted coverings of M^4 and CP_2.

Few years ago came the realization that it could be only effective but have same practical implications. The basic observation was that the effective hierarchy need not be postulated separately but follows as a prediction from the vacuum degeneracy of Kähler action. In this formulation Planck constant at fundamental level has its standard value and its effective values come as its integer multiples so that one should write $\hbar_{eff} = n\hbar$ rather than $\hbar = n\hbar_0$ as I have done. For most practical purposes the states in question would behave as if Planck constant were an integer multiple of the ordinary one. In this formulation the singular covering of the embedding space became only a convenient auxiliary tool. It is no more necessary to assume that the covering reduces to a Cartesian product of singular coverings of M^4 and CP_2 but for some reason I kept this assumption.

The formulation based on multi-furcations of space-time surfaces to N branches. For some reason I assumed that they are simultaneously present. This is too restrictive an assumption. The N branches are very much analogous to single particle states and second quantization allowing all $0 < n \leq N$-particle states for given N rather than only N-particle states looks very natural. As a matter fact, this interpretation was the original one, and led to the very speculative and fuzzy notion of N-atom, which I later more or less gave up. Quantum multi-furcation could be the root concept implying the effective hierarchy of Planck constants, anyons and fractional charges, and related notions- even the notions of N-nuclei, N-atoms, and N-molecules.

3.2.1 Basic Physical Ideas

The basic phenomenological rules are simple and there is no need to modify them.

1. The phases with non-standard values of effective Planck constant are identified as dark matter. The motivation comes from the natural assumption that only the particles with the same value of effective Planck can appear in the same vertex. One can illustrate the situation in terms of the book metaphor. Embedding spaces with different values of Planck constant form a book like structure and matter can be transferred between different pages only through the back of the book where the pages are glued together. One important implication is that light exotic charged particles lighter than weak bosons are possible if they have non-standard value of Planck constant. The standard argument excluding them is based on decay widths of weak bosons and has led to a neglect of large number of particle physics anomalies [K112].

2. Large effective or real value of Planck constant scales up Compton length - or at least de Broglie wave length - and its geometric correlate at space-time level identified as size scale of the space-time sheet assignable to the particle. This could correspond to the Kähler magnetic flux tube for the particle forming consisting of two flux tubes at parallel space-time sheets and short flux tubes at ends with length of order CP_2 size.

   This rule has far reaching implications in quantum biology and neuroscience since macroscopic quantum phases become possible as the basic criterion stating that macroscopic quantum phase becomes possible if the density of particles is so high that particles as Compton length sized objects overlap. Dark matter therefore forms macroscopic quantum phases. One implication is the explanation of mysterious looking quantal effects of ELF radiation in EEG frequency range on vertebrate brain: $E = hf$ implies that the energies for the ordinary value of Planck constant are much below the thermal threshold but large value of Planck constant changes the situation. Also the phase transitions modifying the value of Planck constant and changing the lengths of flux tubes (by quantum classical correspondence) are crucial as also reconnections of the flux tubes.

   The hierarchy of Planck constants suggests also a

   new interpretation for FQHE (see `http://tinyurl.com/y89xp4bu`) (fractional quantum Hall effect) [K75] in terms of anyonic phases with non-standard value of effective Planck constant realized in terms of the effective multi-sheeted covering of embedding space: multi-sheeted space-time is to be distinguished from many-sheeted space-time.

3. In astrophysics and cosmology the implications are even more dramatic if one believes that also $\hbar_{gr}$ corresponds to effective Planck constant interpreted as number of sheets of multi-furcation. It was Nottale (see `http://tinyurl.com/ya6f3s4l`) [E6] who first introduced the notion of gravitational Planck constant as $\hbar_{gr} = GMm/v_0$, $v_0 < 1$ has interpretation as velocity light parameter in units $c = 1$. This would be true for $GMm/v_0 \geq 1$. The interpretation of $\hbar_{gr}$ in TGD framework is as an effective Planck constant associated with space-time sheets mediating gravitational interaction between masses M and m. The huge value of $\hbar_{gr}$ means that the integer $\hbar_{gr}/\hbar_0$ interpreted as the number of sheets of covering is gigantic and that Universe possesses gravitational quantum coherence in super-astronomical scales for masses which are large. This would suggest that gravitational radiation is emitted as dark gravitons which decay to pulses of ordinary gravitons replacing continuous flow of gravitational radiation.

It must be however emphasized that the interpretation of $\hbar_{gr}$ could be different, and it will be found that one can develop an argument demonstrating how $\hbar_{gr}$ with a correct order of magnitude emerges from the effective space-time metric defined by the anti-commutators appearing in the Kähler-Dirac equation.

4. Why Nature would like to have large effective value of Planck constant? A possible answer relies on the observation that in perturbation theory the expansion takes in powers of gauge couplings strengths $\alpha = g^2/4\pi\hbar$. If the effective value of $\hbar$ replaces its real value as one might expect to happen for multi-sheeted particles behaving like single particle, α is scaled down and perturbative expansion converges for the new particles. One could say that Mother Nature loves theoreticians and comes in rescue in their attempts to calculate. In quantum gravitation the problem is especially acute since the dimensionless parameter $GMm/\hbar$ has gigantic value. Replacing $\hbar$ with $\hbar_{gr} = GMm/v_0$ the coupling strength becomes $v_0 < 1$.

3.2.2 Space-Time Correlates For The Hierarchy Of Planck Constants

The hierarchy of Planck constants was introduced to TGD originally as an additional postulate and formulated as the existence of a hierarchy of embedding spaces defined as Cartesian products of singular coverings of M^4 and CP_2 with numbers of sheets given by integers n_a and n_b and $\hbar = n\hbar_0$. $n = n_a n_b$.

With the advent of zero energy ontology, it became clear that the notion of singular covering space of the embedding space could be only a convenient auxiliary notion. Singular means that the sheets fuse together at the boundary of multi-sheeted region. The effective covering space emerges naturally from the vacuum degeneracy of Kähler action meaning that all deformations of canonically imbedded M^4 in $M^4 \times CP_2$ have vanishing action up to fourth order in small perturbation. This is clear from the fact that the induced Kähler form is quadratic in the gradients of CP_2 coordinates and Kähler action is essentially Maxwell action for the induced Kähler form. The vacuum degeneracy implies that the correspondence between canonical momentum currents $\partial L_K/\partial(\partial_\alpha h^k)$ defining the Kähler-Dirac gamma matrices [K119] and gradients $\partial_\alpha h^k$ is not one-to-one. Same canonical momentum current corresponds to several values of gradients of embedding space coordinates. At the partonic 2-surfaces at the light-like boundaries of CD carrying the elementary particle quantum numbers this implies that the two normal derivatives of h^k are many-valued functions of canonical momentum currents in normal directions.

Multi-furcation is in question and multi-furcations are indeed generic in highly non-linear systems and Kähler action is an extreme example about non-linear system (see **Fig.** `http://tgdtheory.fi/appfigures/planckhierarchy.jpg`, or **Fig. ??** in the appendix of this book). What multi-furcation means in quantum theory? The branches of multi-furcation are obviously analogous to single particle states. In quantum theory second quantization means that one constructs not only single particle states but also the many particle states formed from them. At space-time level single particle states would correspond to N branches b_i of multi-furcation carrying fermion number. Two-particle states would correspond to 2-fold covering consisting of 2 branches b_i and b_j of multi-furcation. $N-$particle state would correspond to N-sheeted covering with all branches present and carrying elementary particle quantum numbers. The branches coincide at the partonic 2-surface but since their normal space data are different they correspond to different tensor product factors of state space. Also now the factorization $N = n_a n_b$ occurs but now n_a and n_b would relate to branching in the direction of space-like 3-surface and light-like 3-surface rather than M^4 and CP_2 as in the original hypothesis.

In light of this the working hypothesis adopted during last years has been too limited: for some reason I ended up to propose that only N-sheeted covering corresponding to a situation in which all N branches are present is possible. Before that I quite correctly considered more general option based on intuition that one has many-particle states in the multi-sheeted space. The erratic form of the working hypothesis has not been used in applications.

Multi-furcations relate closely to the quantum criticality of Kähler action. Feigenbaum bifurcations (see `http://tinyurl.com/2swb2p`) represent a toy example of a system which via successive bifurcations approaches chaos. Now more general multi-furcations in which each branch of given multi-furcation can multi-furcate further, are possible unless on poses any additional conditions. This allows to identify additional aspect of the geometric arrow of time. Either the positive or negative energy part of the zero energy state is "prepared" meaning that single n-sub-furcations of N-furcation is selected. The most general state of this kind involves superposition of various n-sub-furcations.

3.2.3 Basic Phenomenological Rules Of Thumb In The New Framework

It is important to check whether or not the refreshed view about dark matter is consistent with existent rules of thumb.

1. The interpretation of quantized multi-furcations as WCW anyons explains also why the effective hierarchy of Planck constants defines a hierarchy of phases which are dark relative to each other. This is trivially true since the phases with different number of branches in multi-furcation correspond to disjoint regions of WCW so that the particles with different effective value of Planck constant cannot appear in the same vertex.

2. The phase transitions changing the value of Planck constant are just the multi-furcations and can be induced by changing the values of the external parameters controlling the properties of preferred extremals. Situation is very much the same as in any non-linear system.

3. In the case of massless particles the scaling of wavelength in the effective scaling of $\hbar$ can be understood if dark n-photons consist of n photons with energy E/n and wavelength $n\lambda$.

4. For massive particle it has been assumed that masses for particles and they dark counterparts are same and Compton wavelength is scaled up. In the new picture this need not be true. Rather, it would seem that wave length are same as for ordinary electron.

   On the other hand, p-adic thermodynamics predicts that massive elementary particles are massless most of the time. ZEO predicts that even virtual wormhole throats are massless. Could this mean that the picture applying on massless particle should apply to them at least at relativistic limit at which mass is negligible. This might be the case for bosons but for fermions also fermion number should be fractionalized and this is not possible in the recent picture. If one assumes that the n-electron has same mass as electron, the mass for dark single electron state would be scaled down by $1/n$. This does not look sensible unless the p-adic length defined by prime is scaled down by this fact in good approximation.

   This suggests that for fermions the basic scaling rule does not hold true for Compton length $\lambda_c = \hbar_m$. Could it however hold for de-Broglie lengths $\lambda = \hbar/p$ defined in terms of 3-momentum? The basic overlap rule for the formation of macroscopic quantum states is indeed formulated for de Broglie wave length. One could argue that an $1/N$-fold reduction of density that takes place in the de-localization of the single particle states to the N branches of the cover, implies that the volume per particle increases by a factor N and single particle wave function is de-localized in a larger region of 3-space. If the particles reside at effectively one-dimensional 3-surfaces - say magnetic flux tubes - this would increase their de Broglie wave length in the direction of the flux tube and also the length of the flux tube. This seems to be enough for various applications.

One important notion in TGD inspired quantum biology is dark cyclotron state.

1. The scaling $\hbar \rightarrow k\hbar$ in the formula $E_n = (n+1/2)\hbar eB/m$ implies that cyclotron energies are scaled up for dark cyclotron states. What this means microscopically has not been obvious but the recent picture gives a rather clearcut answer. One would have k-particle state formed from cyclotron states in N-fold branched cover of space-time surface. Each branch would carry magnetic field B and ion or electron. This would give a total cyclotron energy equal to kE_n. These cyclotron states would be excited by k-photons with total energy $E = khf$ and for large enough value of k the energies involved would be above thermal threshold. In the case of Ca^{++} one has $f = 15$ Hz in the field $B_{end} = .2$ Gauss. This means that the value of $\hbar$ is at least the ratio of thermal energy at room temperature to $E = hf$. The thermal frequency is of order 10^{12} Hz so that one would have $k \simeq 10^{11}$. The number branches would be therefore rather high.

2. It seems that this kinds of states which I have called cyclotron Bose-Einstein condensates could make sense also for fermions. The dark photons involved would be Bose-Einstein condensates of k photons and wall of them would be simultaneously absorbed. The biological meaning of this would be that a simultaneous excitation of large number of atoms or molecules can take place if they are localized at the branches of N-furcation. This would make possible coherent macroscopic changes. Note that also Cooper pairs of electrons could be $n = 2$-particle states associated with N-furcation.

There are experimental findings suggesting that photosynthesis involves de-localized excitations of electrons and it is interesting so see whether this could be understood in this framework.

1. The TGD based model relies on the assumption that cyclotron states are involved and that dark photons with the energy of visible photons but with much longer wavelength are involved. Single electron excitations (or single particle excitations of Cooper pairs) would generate negentropic entanglement automatically.

2. If cyclotron excitations are the primary ones, it would seem that they could be induced by dark N-photons exciting all N electrons simultaneously. N-photon should have energy of a visible photon. The number of cyclotron excited electrons should be rather large if the total excitation energy is to be above thermal threshold. In this case one could not speak about cyclotron excitation however. This would require that solar photons are transformed to n-photons in N-furcation in biosphere.

3. Second - more realistic looking - possibility is that the incoming photons have energy of visible photon and are therefore $n = 1$ dark photons de-localized to the branches of the N-furcation. They would induce de-localized single electron excitation in WCW rather than 3-space.

3.2.4 Charge Fractionization And Anyons

It is easy to see how the effective value of Planck constant as an integer multiple of its standard value emerges for multi-sheeted states in second quantization. At the level of Kähler action one can assume that in the first approximation the value of Kähler action for each branch is same so that the total Kähler action is multiplied by n. This corresponds effectively to the scaling $\alpha_K \rightarrow \alpha_K/n$ induced by the scaling $\hbar_0 \rightarrow n\hbar_0$.

Also effective charge fractionization and anyons emerge naturally in this framework.

1. In the ordinary charge fractionization (see `http://tinyurl.com/26tmhoe`) the wave function decomposes into sharply localized pieces around different points of 3-space carrying fractional charges summing up to integer charge. Now the same happens at at the level of WCW ("world of classical worlds") rather than 3-space meaning that wave functions in E^3 are replaced with wave functions in the space-time of 3-surfaces (4-surfaces by holography implied by General Coordinate Invariance) replacing point-like particles. Single particle wave function in WCW is a sum of N sharply localized contributions: localization takes place around one particular branch of the multi-sheeted space time surface. Each branch carries a fractional charge q/N for teh analogs of plane waves.

   Therefore all quantum numbers are additive and fractionization is only effective and observable in a localization of wave function to single branch occurring with probability $p = 1/N$ from which one can deduce that charge is q/N.

2. The is consistent with the proposed interpretation of dark photons/gravitons since they could carry large spin and this kind of situation could decay to bunches of ordinary photons/gravitons. It is also consistent with electromagnetic charge fractionization and fractionization of spin.

3. The original - and it seems wrong - argument suggested what might be interpreted as a genuine fractionization for orbital angular momentum and also of color quantum numbers, which are analogous to orbital angular momentum in TGD framework. The observation was that a rotation through 2π at space-time level moving the point along space-time surface

leads to a new branch of multi-furcation and $N+1$: th branch corresponds to the original one. This suggests that angular momentum fractionization should take place for M^4 angle coordinate ϕ because for it 2π rotation could lead to a different sheet of the effective covering.

The orbital angular momentum eigenstates would correspond to waves $exp(i\phi m/N)$, $m = 0, 2, ..., N-1$ and the maximum orbital angular momentum would correspond the sum $\sum_{m=0}^{N-1} m/N = (N-1)/2$. The sum of spin and orbital angular momentum be therefore fractional.

The different prediction is due to the fact that rotations are now interpreted as flows rotating the points of 3-surface along 3-surface rather than rotations of the entire partonic surface in embedding space. In the latter interpretation the rotation by 2π does nothing for the 3-surface. Hence fractionization for the total charge of the single particle states does not take place unless one adopts the flow interpretation. This view about fractionization however leads to problems with fractionization of electromagnetic charge and spin for which there is evidence from fractional quantum Hall effect.

3.2.5 What About The Relationship Of Gravitational Planck Constant To Ordinary Planck Constant?

Gravitational Planck constant is given by the expression $\hbar_{gr} = GMm/v_0$, where $v_0 < 1$ has interpretation as velocity parameter in the units $c = 1$. Can one interpret also $\hbar_{gr}$ as effective value of Planck constant so that its values would correspond to multi-furcation with a gigantic number of sheets. This does not look reasonable.

Could one imagine any other interpretation for $\hbar_{gr}$? Could the two Planck constants correspond to inertial and gravitational dichotomy for four-momenta making sense also for angular momentum identified as a four-vector? Could gravitational angular momentum and the momentum associated with the flux tubes mediating gravitational interaction be quantized in units of $\hbar_{gr}$ naturally?

1. Gravitational four-momentum can be defined as a projection of the M^4-four-momentum to space-time surface. It's length can be naturally defined by the effective metric $g_{eff}^{\alpha\beta}$ defined by the anti-commutators of the modified gamma matrices. Gravitational four-momentum appears as a measurement interaction term in the Kähler-Dirac action and can be restricted to the space-like boundaries of the space-time surface at the ends of CD and to the light-like orbits of the wormhole throats and which induced 4- metric is effectively 3-dimensional.

2. At the string world sheets and partonic 2-surfaces the effective metric degenerates to 2-D one. At the ends of braid strands representing their intersection, the metric is effectively 4-D. Just for definiteness assume that the effective metric is proportional to the M^4 metric or rather - to its M^2 projection: $g_{eff}^{kl} = K^2 m^{kl}$.

   One can express the length squared for momentum at the flux tubes mediating the gravitational interaction between massive objects with masses M and m as

$$g_{eff}^{\alpha\beta} p_\alpha p_\beta = g_{eff}^{\alpha\beta} \partial_\alpha h^k \partial_\beta h^l p_k p_l \equiv g_{eff}^{kl} p_k p_l = n^2 \frac{\hbar^2}{L^2} \quad . \tag{3.2.1}$$

   Here L would correspond to the length of the flux tube mediating gravitational interaction and p_k would be the momentum flowing in that flux tube. $g_{eff}^{kl} = K^2 m^{kl}$ would give

$$p^2 = \frac{n^2 \hbar^2}{K^2 L^2} \quad .$$

   $\hbar_{gr}$ could be identifed in this simplified situation as $\hbar_{gr} = \hbar/K$.

3. Nottale's proposal requires $K = GMm/v_0$ for the space-time sheets mediating gravitational interacting between massive objects with masses M and m. This gives the estimate

$$p_{gr} = \frac{GMm}{v_0}\frac{1}{L} \quad . \tag{3.2.2}$$

For $v_0 = 1$ this is of the same order of magnitude as the exchanged momentum if gravitational potential gives estimate for its magnitude. v_0 is of same order of magnitude as the rotation velocity of planet around Sun so that the reduction of v_0 to $v_0 \simeq 2^{-11}$ in the case of inner planets does not mean that the propagation velocity of gravitons is reduced.

4. Nottale's formula requires that the order of magnitude for the components of the energy momentum tensor at the ends of braid strands at partonic 2-surface should have value GMm/v_0. Einstein's equations $T = \kappa G + \Lambda g$ give a further constraint. For the vacuum solutions of Einstein's equations with a vanishing cosmological constant the value of h_{gr} approaches infinity. At the flux tubes mediating gravitational interaction one expects T to be proportional to the factor GMm simply because they mediate the gravitational interaction.

5. One can consider similar equation for gravitational angular momentum:

$$g_{eff}^{\alpha\beta} L_\alpha L_\beta = g_{eff}^{kl} L_k L_l = l(l+1)\hbar^2 \quad . \tag{3.2.3}$$

This would give under the same simplifying assumptions

$$L^2 = l(l+1)\frac{\hbar^2}{K^2} \quad . \tag{3.2.4}$$

This would justify the Bohr quantization rule for the angular momentum used in the Bohr quantization of planetary orbits.

Maybe the proposed connection might make sense in some more refined formulation. In particular the proportionality between $m_{eff}^{kl} = Km^{kl}$ could make sense as a quantum average. Also the fact, that the constant v_0 varies, could be understood from the dynamical character of m_{eff}^{kl}.

3.3 Dark Matter And Living Matter

In the sequel general ideas about the role of dark matter in condensed matter physics are described.

3.3.1 Dark Matter And Mind: General Ideas

Dark matter is identified as a macroscopic quantum phases with large $\hbar$.

An additional assumption that I have considered is that dark matter particles have complex conformal weights. This assumption is however not necessary. The sum of the imaginary parts of conformal weights was assumed for number theoretical reasons to be expressible as sums of imaginary parts for the zeros of Riemann Zeta would define a new conserved quantum number, "scaling momentum" [K29]. The conjugation of the complex conformal weight would distinguish between quantum states and their phase conjugates. This point is important since phase conjugate photons represent negative energy signals propagating into geometric past, assumed to be distinguishable from positive energy signals propagating into geometric future, play a key role in TGD based biology: this distinction cannot be made in QFT context.

Living matter could be matter with a large value of $\hbar$ and hence dark, and form conformally confined blobs behaving like single units with extremely quantal properties, including free will and intentional action in time scales familiar to us. Dark matter would be the physics counterapart for the mysterious vital force.

Any system for which some interaction becomes so strong that perturbation theory does not work, could give rise to this kind of system in a phase transition in which $\hbar$ increases to not lose perturbativity gives rise to this kind of "super-quantal" matter. In this sense emergence would corresponds to strong coupling. The interpretation would be that strong fluctuations at strong coupling give rise to a large number of orbifold points so that the S-matrix elements to a phase with larger Planck constant become large. Dark matter made possible by dynamical $\hbar$ is necessary for macroscopic and macro-temporal quantum coherence and is thus prerequisite for emergence.

Physically large $\hbar$ means a larger unit for quantum numbers and this requires that single particle states form larger particle like units. This kind of collective states with weak mutual interactions are of course very natural in strongly interacting systems. The N sheets of $M^4_{\pm}$, where N is the order of group G_b involved with the Jones inclusion in question. Each partonic 2-surface appears as N geometrically identical copies which can however carry different fermionic quantum numbers. Hence the N-fold space-time sheet carry up to N G_b invariant partons with identical quantum numbers so that an effective breaking of Fermi statistics becomes possible.

A possible implication would be the notion of N-atom, which at the level of quantum jumps quantum jumps integrate effectively to single quantum jump and longer moments of consciousness result. Entire hierarchy of size scales for matter blobs is predicted corresponding to values of $\hbar$. The larger the value of $\hbar$, the longer the characteristic time scale of consciousness and of a typical life cycle.

In RHIC color glass condensate resembles incompressible liquid. Liquids might be liquids because they contain some dark matter at magnetic/Z^0 magnetic flux tubes (darkness follows from the large value of $\hbar$). Incompressibility of liquid could correspond to maximal density of flux tubes and to the fact that magnetic fields have no sources. In accordance with the previous ideas already water could be living and conscious system in some primitive sense.

The notion of field body in turn means that dark matter at the magnetic flux tubes would serve as an intentional agent using biological body as a motor instrument and sensory receptor. Dark matter would be the miraculous substance that living systems are fighting for, and perhaps the most important substance in metabolic cycle.

Hierarchy of dark matters and hierarchy of minds

The notion of dark matter is a relative concept in the sense that dark matter is invisible from the point of view of the ordinary matter. One can imagine an entire hierarchy of dark matter structures corresponding to the hierarchy of space-time sheets for which p-adic length scales differ by a factors $r = 2^k$ allowed by Mersenne hypothesis. The fact that proton-electron mass ratio is near 2^{11} inspires the question whether the multiples of 11 could be preferred values of k. The BE condensates of N_{cr} ordinary matter particles would serve as dynamical units for "doubly dark matter" invisible to the dark matter. The above discussed criticality criterion can be applied at all levels of the hierarchy to determine the value of the dynamical interaction strength for which BE condensates of BE condensates are formed.

The most interesting new physics would emerge from the interaction between length scales with different Planck constant but same scaled up variant of the p-adic length scale made possible by the decay of BE condensates of dark photons to ordinary photons having wavelength shorter by a factor $1/r$. This interaction could provide the royal road to the quantitative understanding how living matter manages to build up extremely complex coherent interactions between different length and time scales.

In the time domain dark matter hierarchy could allow to understand how moments of consciousness organize to a hierarchy with respect to the time scales of moment of consciousness coming as 2^k multiples of CP_2 time scale. Even human life span could be seen as single moment of consciousness at $k = 154 = 14 \times 11$ level of the dark matter hierarchy.

Realization of intentional action and dark matter hierarchy

How long length scales are able to control the dynamics in short length scales so that the extremely complex process extending down to atomic length scales realizing my intention to write this word is possible. This question has remained without a convincing answer in the recent day biology and there strong objections against the idea that this process is planned and initiated at neuronal level.

I have proposed a concrete mechanism for the realization of intentional action in terms of time mirror mechanism (see **Fig.** `http://tgdtheory.fi/appfigures/timemirror.jpg` or **Fig. ??** in the appendix of this book) involving the emission of negative energy photons and proceeding as a cascade in a reversed direction of geometric time from long to short length scales [?]. This cascade would induce as a reaction analogous processes proceeding in the normal direction of geometric time as a response and would correspond to the neural correlates of intentional action in very general sense of the word.

The counterparts for the negative energy signals propagating to the geometric past would be phase conjugate (negative energy) laser beams identifiable as Bose-Einstein condensates of dark photons. In the time reflection these beams would transform to positive energy dark matter photons eventually decaying to ordinary photons. The space-time correlate would be MEs decaying into MEs and eventually to CP_2 type vacuum extremals representing ordinary photons.

The realization of intentional action as desires of boss expressed to lower level boss would naturally represented the decay of the phase conjugate dark laser beam to lower level laser beams decaying to lower level laser beams decaying to.... This would represent the desire for action whereas the time reflection at some level would represent the realization desire as stepwise decay to lower level laser beams and eventually to ordinary photons. The strong quantitative prediction would be that these levels correspond to a length and time scale hierarchies consistent with Mersenne hypothesis or more general ruler and compass hypothesis.

Wave-length hierarchy, coherent metabolism, and proton-electron mass ratio

The fact that a given wavelength corresponds to energies related to each other by a scaling with powers of v_0 provides a mechanism allowing to transfer energy from long to short long scales by a de-coherence occurring either in the standard or reversed direction of geometric time. De-coherence in the reversed direction of time would be associated with mysterious looking processes like self-assembly allowing thus an interpretation as a normal decay process in reversed time direction.

It is perhaps not an accident that the value of $v_0 \simeq 4.6\times10^{-4}$ is not too far from the ratio of $m_e/m_p \simeq 5.3\times10^{-4}$ giving the ratio of zero point kinetic energies of proton and electron for a given space-time sheet. Proton mass ratio $m_p/m_e = 1836.15267261$ corresponds in good approximation to $n = 2^2\times3^3\times17 = 1836$. This integer is of form $n = 9\times n_F$. This co-incidence could in principle make possible a metabolic mechanism in which dark protons and ordinary electrons co-operate in the sense that dark protons generate dark photon BE condensates with wave length λ transforming to ordinary photons with wavelength $v_0\lambda$ absorbed by ordinary electrons.

Some examples are in order to illustrate these ideas.

1. As already found, in the case of dark atoms the scaling of binding energies as $1/\hbar^2$ allows the coupling of $\sim$ 9 cm scale of brain hemisphere with the length scale $\sim$ 50 μm of large neuron. $N_{cr} \leq 137$ ordinary IR photons would be emitted in single burst and interacting with neuron.

2. For a non-relativistic particle in a box of size L the energy scale is given by $E_1 = \hbar^2\pi^2/2mL^2$ so that the visible photons emitted would have energy scaled up by a factor $(\hbar_s/\hbar)^2 \simeq 4\times10^6$. The collective dropping of N_{cr} dark protons to larger space-time sheet would liberate a laser beam of dark photons with energy equal to the liberated zero point kinetic energy. For instance, for the p-adic length scale $L(k = 159 = 3\times53) \simeq .63$ μm this process would generate laser beam of IR dark photons with energy $\sim .5$ eV also generated by the dropping of ordinary protons from $k = 137$ atomic space-time sheet. There would thus be an interaction between dark protons in cell length scale and ordinary protons in atomic length scale. For instance, the dropping of dark protons in cell length scale could induce driving of protons back to the atomic space-time sheet essential for the metabolism [K49]. Similar argument applies to electrons with the scale of the zero point kinetic energy about 1 keV.

   In many-sheeted space-time (see **Fig.** `http://tgdtheory.fi/appfigures/manysheeted.jpg` or **Fig.** 9 in the appendix of this book) particles topologically condense at all space-time sheets having projection to given region of space-time so that this option makes sense only near the boundaries of space-time sheet of a given system. Also p-adic phase transition increasing the size of the space-time sheet could take place and the liberated energy would correspond to the reduction of zero point kinetic energy. In this case the process would occur coherently for all particles. Particles could be transferred from a portion of magnetic flux tube portion to another one with different value of magnetic field and possibly also of Planck constant h_{eff} so that cyclotron energy would be liberated.

In the sequel the early version of the model assigning metabolic energy quantum to the dropping of protons is only considered. In [K80] a model of metabolism associating the metabolic energy quantum to the change of cyclotron energy is discussed.

3. If the energy spectrum associated with the conformational degrees of freedom of proteins, which corresponds roughly to a frequency scale of 10 GHz remains also invariant in the phase transition to dark protein state, coherent emissions of dark photons with microwave wave lengths would generate ordinary infrared photons. For instance, metabolic energy quanta of $\sim .5$ eV could result from macroscopic Bose-Einstein condensates of 58 GHz dark photons resulting from the oscillations in the conformational degrees of freedom of dark proteins. A second option is that the conformal energies are scaled by $\hbar_s/\hbar$ (ω would remain invariant). In this case these coherent excitations would generate ordinary photons with energy of about 1 keV able to drive electrons back to the atomic $k = 137$ space-time sheet.

4. Since magnetic flux tubes have a profound role in TGD inspired theory of consciousness, it is interesting to look also for the behavior of effective magnetic transition energies in the phase transition to the dark matter phase. This transition increases the scale of the magnetic interaction energy so that anomalously large magnetic spin splitting $\hbar_s eB/m$ in the external magnetic field could serve as a signature of dark atoms. The dark transition energies relate by a factor $\hbar_s/\hbar$ to the ordinary magnetic transition energies.

For instance, in the magnetic field $B_{end} = 2B_E/5 = .2$ Gauss, where $B_E = .5$ Gauss is the nominal value of the Earth's magnetic field, explaining the effects of ELF em fields on vertebrate brain, dark electron cyclotron frequency is 6×10^5 Hz and corresponds to ordinary microwave photon with frequency ~ 1.2 GHz and wavelength $\lambda \simeq 25$ cm. For proton the cyclotron frequency of 300 Hz would correspond to energy of ordinary photon with frequency of 6×10^5 Hz and could induce electronic cyclotron transitions and spin flips in turn generating for instance magneto-static waves.

It is easy to imagine a few step dark matter hierarchy connecting EEG frequencies of dark matter with frequencies of visible light for ordinary photons. This kind of hierarchy would give considerable concreteness for the notion of magnetic body having size scale of Earth.

A connection with bio-photons

The biologically active radiation at UV energies was first discovered by Russian researcher Gurwitz using a very elegant experimental arrangement [I26]. Gurwitz christened this radiation mitogenetic radiation since it was especially intense during the division of cell.

A direct proof for the biological activity of mitogenetic radiation consisted of a simple experiment in which either quartz or glass plate was put between two samples. The first sample contained already growing onion roots whereas the second sample contained roots which did not yet grow. In the case of quartz plate no stimulation of growth occurred unlike for glass plate. Since quartz is not transparent to UV light whereas the ordinary glass is, the conclusion was that the stimulation of growth is due to UV light.

The phenomenon was condemned by skeptics as a pseudo science and only the modern detection technologies demonstrated its existence [I56], and mitogenetic radiation became also known as bio-photons (the TGD based model for bio-photons is discussed in [K49]). Bio-photons form a relatively featureless continuum at visible wavelengths continuing also to UV energies, and are believed to be generated by DNA or at least to couple with DNA. The emission of bio-photons is most intense from biologically active organisms and the irradiation by UV light induces an emission of mitogenetic radiation by a some kind of amplification mechanism. It has been suggested that bio-photons represent some kind of leakage of a coherent light emitted by living matter.

According to Russian researcher V. M. Injushin [I69] , mitochondrios emit red light at wavelengths 620 nm and 680 nm corresponding to energies 2 eV and 1.82 eV. According to the same source, the nucleus of cell sends UV light at wavelengths 190, 280 and 330 nm corresponding to the energies 6.5, 4.4 and 3.8 eV. The interpretation as a kind of leakage of coherent light would conform with the identification in terms of BE condensates of dark photons with $\hbar_s/\hbar \simeq 2^{k_d}$ decaying to photons with energies visible and UV range. The model for the cell membrane as almost vacuum extremal [K37] leads to a successful prediction of the frequencies of peak sensitivity for four kinds of photoreceptors and allows to identify bio-photons as decay products of dark Josephson photons. Also EEG photons can be understood as decay products of Josephson photons. Also a fractal generalization of EEG emerges.

The analysis of Kirlian photographs has shown that the pattern of visible light emitted by various body parts, for instance ear, code information about other body parts [I100]. These bio-holograms for which a general model is discussed in [K19] could be realized as dark photon laser beams.

In phantom DNA effect [I54] a chamber containing DNA is irradiated with a visible laser light and the DNA generates as a response coherent visible radiation at same wavelength. Strangely enough, the chamber continues to emit weak laser light even after the removal of DNA. This effect could be due to the decay of a dark photon BE condensate remaining in the chamber. Also the findings of Peter Gariaev [I47] about the effects of visible laser light on DNA, in particular the stimulated emission of radio waves in kHz-MHz frequency range might also relate to dark photons somehow.

A connection with the scaling law of homeopathy

The value of the parameter $1/v_0 \simeq 2083$ is essentially the ratio of CP_2 radius and Planck length scale (as also the ratio of Compton lengths of electron and proton) and rather near to $2^{11} = 2048$. This inspired the idea that powers of 2^{11} might define a hierarchy of preferred value of Planck constant. It however seems that this hypothesis is quite too restrictive. Interestingly, much larger number $2 \times 10^{11} \simeq 3 \times 2^{36}$ appears in the simplest form for what I have christened the scaling law of homeopathy [K44]. This rule has been proposed on basis of experimental findings [I31] but has no convincing theoretical justification. The scaling law of homeopathy states that high frequency em radiation transforms to a low frequency radiation and vice versa preferably with the frequency ratio $f_{high}/f_{low} \simeq 2 \times 10^{11}$.

The proposed hierarchy of dark matter and ensuing hierarchy of dark laser beams decaying into lower level beams might provide a deeper explanation for the scaling law of homeopathy. The factor 2×10^{11} is with 3 per cent accuracy equal to the integer $n_F = 3 \times 2^{36} \simeq 2.06 \times 10^{11}$ characterizing ruler and compass quantum phase. Hence the interpretation in terms of a phase transition leading from a phase with a large value of Planck constant $\hbar = n_F \hbar_0$ to ordinary phase is possible.

In [K44] I have discussed some mechanisms for the transformation of high energy photons to low energy photons consistent with the rule and proposed a generalization of the rule based on p-adic length scale hypothesis. For instance, high energy visible photons of frequency f could induce an excitation of the receiving system having same frequency, propagating with velocity $\beta = v/c \simeq 10^{-11}/2$, and having wave length equal $\lambda_0 = f/v = \lambda/\beta$. This excitation would in turn couple to photons of wavelength λ_0 and frequency $f_0 = \beta f$.

3.3.2 Dark Matter Hierarchy, Sensory Representations, And Motor Action

Dark matter hierarchy allows to develop a detailed model for how magnetic bodies use biological bodies as sensory receptors and motor instruments [K37] leading among other things to a generalization of the notion of genome.

For ordinary quantum mechanics photons at EEG frequencies correspond to ridiculously small energies. Dark matter hierarchy is accompanied by a hierarchy of EEGs and its generalizations with the scalings of frequencies predicted by Mersenne hypothesis to come as powers 2^{-k_d} [K37]. For $k_d = 44$ the energies of EEG photons are above thermal threshold at room temperature for $f \geq 1$ Hz, .

The fact that arbitrarily small frequencies can correspond to energies above thermal threshold at higher levels of dark matter hierarchy implies that photons with arbitrarily low frequencies can have sizeable physical effects on matter. This conforms with the findings about the effects of

ELF em fields on living matter [K37], and these effects allow to develop a rather detailed model for EEG and identify the parts of EEG correlating with communications of sensory data to the magnetic body and with quantum control performed by the magnetic body [K37].

Bose-Einstein condensates at magnetic flux quanta in astrophysical length scales

The new model for the topological condensation at magnetic flux quanta of Earth's magnetic field is based on the dark matter hierarchy with levels characterized by the value of $\hbar = 2^{k_d}\hbar_0$, where k_d is given by Mersenne hypothesis.

1. There are several levels of dynamics. In topological condensation the internal dynamics of ions is unaffected and $\hbar$ has the ordinary value. The formation of Cooper pairs involves dynamics at relatively lo level of dark matter hierarchy. Also the dynamics of ionic Cooper pairs remains unaffected in the topological condensation to magnetic flux quanta with larger value of Planck constant.

2. Cyclotron energies scale as as $\hbar$ so that for a sufficiently high value of k thermal stability of cyclotron states at room temperature is achieved for given value of field strength.

3. If the flux quanta of Earth's magnetic field correspond to $k = 44$ level of dark matter hierarchy, cyclotron energies $E = (\hbar/2\pi) \times ZeB/Am_p$ are scaled up by a factor 2^{44} from their ordinary values and are above thermal energy at room temperature for $A \leq 233Z$, where Z is the charge of the ion. Even for $Z = 1$ this includes all stable nuclei. Bose-Einstein condensates of bosonic ions are thus possible at room temperatures at Earth's surface.

Fractal hierarchy of magnetic flux sheets

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

1. If Josephson photons are transformed to a bunch of ordinary small $\hbar$ photons magnetic flux tubes can correspond to the ordinary value of Planck constant. If one assumes the quantization of the magnetic flux in the form

$$\int BdA = n\hbar$$

used in super-conductivity, the radius of the flux tube must increase as $\sqrt{\hbar}$ and if the Josephson frequency is reduced to the sound frequency, the value of $\hbar$ codes for the sound frequency. This leads to problems since the transversal thickness of flux tubes becomes too large. This does not however mean that the condition might not make sense: for instance, in the case of flux sheets going through DNA strands the condition might apply.

2. The quantization of magnetic flux could be replaced by a more general condition

$$\oint (p - ZeA)dl = n\hbar \ , \tag{3.3.1}$$

where p represents momentum of particle of super-conducting phase at the boundary of flux tube. In this case also $n = 0$ is possible and poses no conditions on the thickness of the flux tube as a function of $\hbar$. This option looks reasonable in length scales assignable to biological body (say flux tubes assignable to axonal membranes and DNA strands since the charged particles at the boundary of flux tube would act as sources of the magnetic field. At the level of magnetic body of Earth the currents might vanishing and flux quantization would pose a condition of the size of the flux quantum.

As an example consider flux sheets, which have thickness $L(151) = 2.5$ nm carrying magnetic field having strength of Earth's magnetic field. At $k_d = 44$ level of dark matter hierarchy necessary in order that the energies associated with cyclotron frequencies are above thermal threshold these flux sheets would have minimum thickness of DNA double strand and total transversal length $L(169 + 5 \times 22) = L(257) = 1.6 \times 10^8$ km from flux quantization without supra currents.Fux quantization without supra currents is not satisfied at the level of single nucleus or even organism. The simplest possibility is that the flux sheets of cells fuse to larger flux sheets representing organs and organisms and that even the flux sheets assignable to separate organisms fuse in turn to larger flux sheets for which quantization condition for magnetic flux can be satisfied without assuming $n = 0$ and supra currents flowing at the boundaries of flux sheets.

Suppose that the magnetic flux flows in head to tail direction so that the magnetic flux arrives to the human body through a layer of cortical neurons. Assume that the flux sheets traverse through the uppermost layer of neurons and also lower layers and that DNA of each neuronal nuclei define a transversal sections organized along flux sheet like text lines of a book page. The total length of DNA in single human cell is about one meter. It seem that single brain cannot provide the needed total length of DNA if DNA dominates the contribution: this if of course not at all necessarily.

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

Charge entanglement as a tool of generalized motor action

The charge entanglement by W MEs is an essentially new element in the model for generalized motor actions by magnetic body. Also the telepathic sharing of mental images could rely on charge entanglement. The notion was originally applied in the model of nerve pulse generation [K82]. Neutral MEs would in turn be related to communications and memory. The reduction of charge entanglement can induce a quantum jump to a state in which local Bose-Einstein condensates become exotically ionized with certain probability depending on the intensity of W field. Bose-Einstein condensates define pixels of generalized motor maps.

Exotic ionization induces dark plasma oscillations in turn generating various physiological responses such as Ca^{++}, Mg^{++} waves, and nerve pulse patterns giving rise to the motor action as an asymptotic self-organization pattern. Plasma oscillation patterns utilize typically dark microwave photons as metabolic energy. Field code is the correspondence between the spatio-temporal pattern of plasma oscillations and generalized motor action and the number theoretical model for genetic code [K32] generalizes to this context.

Overview about quantum control and coordination

The following general overview about quantum communication and control emerges in this framework.

1. Cyclotron frequencies relate to the control of the biological body by the magnetic body and could be assigned with the magnetic flux sheets going through DNA since it is genome where protein synthesis is initiated and is thus the optimal intermediate step in the cellular control.

2. One of the basic functions of cell membranes is to perceive the chemical environment using various kinds of receptors as sensors. Neurons have specialized to receive symbolic representations of the sensory data of primary sensory organs about the situation in the external world. Receptor proteins would communicate cell level sensory input to the magnetic body via MEs parallel to magnetic flux tubes connecting them to the magnetic body. We ourselves would be in an abstract sense fractally scaled up counterparts of receptor proteins and associated with dark matter iono-lito Josephson junction connecting the parts of magnetosphere below litosphere and above magnetosphere.

3. This picture would explain why the temperature of brain must be in the narrow range 36-37 K to guarantee optimal functionality of the organism. If interior superconductivity is lost, magnetic body receives sensory data but is paralyzed since its desires cannot be realized. If boundary superconductivity is lost, magnetic body can move but is blind.

4. In the length scales below the weak length scale L_w also charged weak bosons behave as massless particles and the exchange of virtual W bosons makes possible a non-local charge transfer. Dark quark-antiquark pairs associated with the color bonds of the atomic nuclei can become charged via the emission of dark W boson and thus produce and exotic ion. The same can happen at the higher levels of dark matter hierarchy. This provides a non-local quantal mechanism inducing or changing electromagnetic polarization in turn inducing ordinary charge flows and thus making possible quantum control.

5. Massless extremals (MEs, topological light rays) serve as correlates for dark bosons. Besides neutral massless extremals (em and Z^0 MEs) TGD predicts also charged massless extremals obtained from their neutral counterparts by a mere color rotation (color and weak quantum numbers are not totally independent in TGD framework). The interpretation of the charged MEs has remained open hitherto. Charged W MEs (hierarchy of WEGs!) could induce long length scale charge entanglement of Bose-Einstein condensates by inducing exotic ionization of ionic nuclei. State function reduction could lead to a state containing a Bose-Einstein condensate in exotically ionized state.

   In this manner the dark charge inside neuron and thus by Faraday's law also membrane potential could be affected by magnetic body. The generation of nerve pulse could rely on the reduction of the resting potential below the critical value by this kind of mechanism inducing charge transfer between cell interior and exterior. The mechanism might apply even in the scale of magnetic body and make possible the control of central nervous system. Also remote mental interactions, in particular telekinesis, might rely on this mechanism.

Summarizing, charged massless extremals could be seen as correlates for non-local quantum control by affecting charge equilibria whereas neutral MEs would serve as correlates for coordination and communication. Color charged MEs could also induce color charge polarization and flows of color charges and thus generate visual color qualia by the capacitor mechanism discussed in [K41].

3.4 MEs And Mes

The development of the model for the detailed identification of the sensory qualia and brain led to a general vision about the evolution of consciousness and information processing in brain. In this section various properties of MEs are summarized.

3.4.1 Massless Extremals

Massless extremals (MEs) are an extremely general solution set of field equations associated with Kähler action [K46] and representing various gauge – and gravitational fields [K70]. Being scale invariant, MEs come in all size scales. The geometry has axial symmetry in the sense that CP_2 coordinates are arbitrary functions of two variables constructed from Minkowski coordinates: light-like coordinate $t-z$ and arbitrary function of the coordinates of the plane orthogonal to the z-axis defining the direction of propagation. The polarization of the electromagnetic field depends on the point of the plane but is temporally constant. MEs represent waves propagating with velocity of light in single direction so that there is no dispersion: preservation of the pulse shape makes MEs ideal for classical communications.

Electric and magnetic parts of various gauge fields are orthogonal to each other and to the direction of propagation. Classical gauge field is sum of a free part plus part having as its source light-like vacuum current. The time dependence of the vacuum current is arbitrary, this is only possible by its light-likeness. This makes it possible to code all kinds of physical information to the time dependence of the vacuum current. MEs can have finite spatial size and in this case they are classical counterparts of virtual photons exchanged between charged particles and represent classical communication between material space-time sheets. MEs carry gravitational waves and also classical Z^0 fields propagating with light velocity.

MEs can also carry constant electric field. In this case either vacuum charges or actual charges near the boundaries of ME contain define the sources of this field. This situation can be also achieved if MEs form double-sheeted structures and wormhole contacts serve as effectively sources of the field. It is quite possible and even plausible that boundary conditions do not allow boundaries at all so that one must have at least double sheeted coverings so that MEs would appear as pairs.

TGD allows to consider also the possibility that the two sheets have opposite time orientations and therefore also opposite classical energies. This kind of structures are obvious candidates for cognitive structures since classical nondeterminism is localized in a finite space-time volume. The Universe could be full of MEs with all possible sizes since they have vanishing action: addition of ME with finite time duration yields new preferred extremal of Kähler action. This suggests that MEs should be of crucial importance in TGD Universe.

MEs serve as receiving and sending quantum antennae [K70]. Light-like vacuum current generates coherent light. Also coherent gravitons are generated. MEs serve also as templates for BE condensation of photons and gravitons with momenta parallel to the light-like vacuum current. Linear structures, say DNA and micro-tubules, are natural but not the only candidates for structures accompanied by MEs. Since MEs are massless, they carry maximal possible momentum. This makes exchange of ME ideal mechanism for locomotion. The possibility of negative energy MEs is especially fascinating since it suggests "buy now, pay later" mechanism of energy production: perhaps living matter uses MEs to generate coherent motions [K73, K72].

Massless extremals as general solutions of field equations

Let $k = (k^0, k^3, 0, 0)$ be a light like vector of M^4 and $u = u(m^1, m^2)$ arbitrary function of the Minkowski coordinates m^1 and m^2 in the plane orthogonal to the direction of the 3-vector $(k^3, 0, 0)$ associated with k. The surfaces defined by the map

$$s^k = f^k(k \cdot m, u) \ , \tag{3.4.1}$$

where f^k and u are arbitrary functions define massless extremals. They describe the propagation of massless fields in the direction of k: the fields are periodic with a period $\lambda = 2\pi/k$ so that only k and its integer multiples are possible wave vectors. The polarization associated with various induced gauge fields depends on the position in (m^1, m^2)-plane and is in the direction of the gradient of u. Field equations involve tensor contractions of the energy momentum tensor and gauge current but these are proportional to kk and k respectively and vanish by the light-likeness of k. Linear superposition holds true only in a restricted sense since both the propagation direction and the polarization direction in each $(m^1, m^2) = const$ plane is fixed.

What is remarkable that these solutions are not solutions of the ordinary Maxwell equations in vacuum: Kähler current density J_K is in general non-vanishing(!) and proportional to the light like four-momentum k. As a consequence, also a light-like electromagnetic current is in general (but not necessarily) present. The interpretation of the em current J as charged elementary particle current is impossible and the correct interpretation as a vacuum current associated with the induced gauge fields. The finite length of the micro-tubule plus the requirement that the total vacuum charge vanishes, implies that the Fourier decompositions of the massless fields contain only integer multiples of the basic four-momentum k. The direct detection of the light-like vacuum current inside a micro-tubule would provide strong support for TGD.

The physical importance of these extremals is suggested by the fact they are in certain sense elementary particle like objects: in fact, the original interpretation was as a model for the exterior space-time of a topologically condensed massless particle. The solution set is also very general involving several arbitrary functions. Although the minimization of the Kähler action favors the formation of Kähler electric fields, massless extremals might well appear as space-time sheets of the effective space-time. These space-time sheets should not contain ordinary charges since their presence implies a transition to the Maxwell phase described in an excellent approximation by the ordinary Maxwell electrodynamics. The fact that vacuum em current and vacuum Einstein tensor do not in general vanish, could mean that massless extremals serve as sources of coherent photons and gravitons.

Massless extremals can also reduce to vacuum extremals of the Kähler action in the case that the CP_2 projection is, in general two-dimensional, Legendre manifold of CP_2. These extremals are however not gravitational vacua.

Generalization of the solution ansatz defining MEs

The solution ansatz for MEs has developed gradually to an increasingly general form and the following formulation is the most general one achieved hitherto. Rather remarkably, it rather closely resembles the solution ansatz for the CP_2 type extremals and has direct interpretation in terms of geometric optics. Equally remarkable is that the latest generalization based on the introduction of the local light-cone coordinates was inspired by quantum holography principle.

The solution ansatz for MEs has developed gradually to an increasingly general form and the following formulation is the most general one achieved hitherto. Rather remarkably, it rather closely resembles the solution ansatz for the CP_2 type extremals and has direct interpretation in terms of geometric optics. Equally remarkable is that the latest generalization based on the introduction of the local light-cone coordinates was inspired by quantum holography principle.

1. Local light-cone coordinates

The solution involves a decomposition of M^4_+ tangent space localizing the decomposition of Minkowski space to an orthogonal direct sum $M^2 \oplus E^2$ defined by light-like wave vector and polarization vector orthogonal to it. This decomposition defines what might be called local light-cone coordinates.

1. Denote by m^i the linear Minkowski coordinates of M^4. Let (S_+, S_-, E_1, E_2) denote local cooordinates of M^4_+ defining a *local* decomposition of the tangent space M^4 of M^4_+ into a direct *orthogonal* sum $M^4 = M^2 \oplus E_2$ of spaces M^2 and E^2. This decomposition has interpretation in terms of the longitudinal and transversal degrees of freedom defined by local light-like four-velocities $v_\pm = \nabla S_\pm$ and polarization vectors $\epsilon_i = \nabla E_i$ assignable to light ray.

2. In accordance with this physical picture, S_+ and S_- define light-like curves and thus satisfy the equation:

$$(\nabla S_\pm)^2 = 0 \quad .$$

   The gradients of $S_\pm$ are obviously analogous to local light like velocities $v = (1, \overline{v})$ and $\tilde{v} = (1, -\overline{v})$. These equations are also obtained in geometric optics from Hamilton Jacobi equation by replacing photon's four-velocity with the gradient ∇S: this is consistent with the interpretation of MEs as Bohr orbits of em field.

3. With these assumptions the coordinates $(S_\pm, E_i)$ define local light-cone coordinates with the metric element having the form

$$ds^2 = g_{S_+S_-} dS_+ dS_- + g_{11} dE_1^2 + g_{22} dE_2^2 \quad .$$

   Conformal transformations of M^4_+ leave the general form of this decomposition invariant. The task is to find all possible local light-cone coordinates defining one-parameter families 2-surfaces defined by the condition $S_i = constant$, $i = + \ or \ = -$, dual to each other and expanding with light velocity.

2. A conformally invariant family of local light-cone coordinates

The simplest solutions to the equations defining local light-cone coordinates are of form $S_\pm = k \cdot m$ giving as a special case $S_\pm = m^0 \pm m^3$. For more general solutions of from

$$S_\pm = m^0 \pm f(m^1, m^2, m^3) \ , \ \ (\nabla_3 f)^2 = 1 \ ,$$

where f is an otherwise arbitrary function, this relationship reads as

$$S_+ + S_- = 2m^0 \ .$$

This condition defines a natural rest frame. One can integrate f from its initial data at some two-dimensional $f = constant$ surface and solution describes curvilinear light rays emanating from this surface and orthogonal to it. The flow velocity field $\overline{v} = \nabla f$ is irrotational so that closed flow lines are not possible in a connected region of space and the condition $\overline{v}^2 = 1$ excludes also closed flow line configuration with singularity at origin such as $v = 1/\rho$ rotational flow around axis.

One can identify E^2 as a local tangent space spanned by polarization vectors and orthogonal to the flow lines of the velocity field $\overline{v} = \nabla f(m^1, m^2, m^3)$. Since the metric tensor of any 3-dimensional space allows always diagonalization in suitable coordinates, one can always find coordinates (E_1, E_2) such that (f, E_1, E_2) form orthogonal coordinates for $m^0 = constant$ hyperplane. Obviously one can select the coordinates E_1 and E_2 in infinitely many ways.

3. Closer inspection of the conditions defining local light-cone coordinates

Whether the conformal transforms of the local light-cone coordinates $\{S_\pm = m^0 \pm f(m^1, m^2, m^3), E_i\}$ define the only possible compositions $M^2 \oplus E^2$ with the required properties, remains an open question. The best that one might hope is that any function S_+ defining a family of light-like curves defines a local decomposition $M^4 = M^2 \oplus E^2$ with required properties.

1. Suppose that S_+ and S_- define light-like vector fields which are not orthogonal (proportional to each other). Suppose that the polarization vector fields $\epsilon_i = \nabla E_i$ tangential to local E^2 satisfy the conditions $\epsilon_i \cdot \nabla S_+ = 0$. One can formally integrate the functions E_i from these condition sonce the initial values of E_i are given at $m^0 = constant$ slice.

2. The solution to the condition $\nabla S_+ \cdot \epsilon_i = 0$ is determined only modulo the replacement

   $$\epsilon_i \rightarrow \hat{\epsilon}_i = \epsilon_i + k \nabla S_+ \ ,$$

   where k is any function. With the choice

   $$k = -\frac{\nabla E_i \cdot \nabla S_-}{\nabla S_+ \cdot \nabla S_-}$$

   one can satisfy also the condition $\hat{\epsilon}_i \cdot \nabla S_- = 0$.

3. The requirement that also $\hat{\epsilon}_i$ is gradient is satisfied if the integrability condition

   $$k = k(S_+)$$

   is satisfiedin this case $\hat{\epsilon}_i$ is obtained by a gauge transformation from ϵ_i. The integrability condition can be regarded as an additional, and obviously very strong, condition for S_- once S_+ and E_i are known.

4. The problem boils down to that of finding local momentum and polarization directions defined by the functions S_+, S_- and E_1 and E_2 satisfying the orthogonality and integrability conditions

   $$(\nabla S_+)^2 = (\nabla S_-)^2 = 0 \ , \quad \nabla S_+ \cdot \nabla S_- \neq 0 \ ,$$

   $$\nabla S_+ \cdot \nabla E_i = 0 \ , \qquad \frac{\nabla E_i \cdot \nabla S_-}{\nabla S_+ \cdot \nabla S_-} = k_i(S_+) \ .$$

   The number of integrability conditions is 3+3 (all derivatives of k_i except the one with respect to S_+ vanish): thus it seems that there are not much hopes of finding a solution unless some discrete symmetry relating S_+ and S_- eliminates the integrability conditions altogether.

A generalization of the spatial reflection $f \to -f$ working for the separable Hamilton Jacobi function $S_\pm = m^0 \pm f$ ansatz could relate S_+ and S_- to each other and trivialize the integrability conditions. The symmetry transformation of M^4_+ must perform the permutation $S_+ \leftrightarrow S_-$, preserve the light-likeness property, map E^2 to E^2, and multiply the inner products between M^2 and E^2 vectors by a mere conformal factor. This encourages the conjecture that all solutions are obtained by conformal transformations from the solutions $S_\pm = m^0 \pm f$.

4. General solution ansatz for MEs for given choice of local light-cone coordinates

Consider now the general solution ansatz assuming that a local wave-vector-polarization decomposition of M^4_+ tangent space has been found.

1. Let $E(S_+, E_1, E_2)$ be an arbitrary function of its arguments: the gradient ∇E defines at each point of E^2 an S_+-dependent (and thus time dependent) polarization direction orthogonal to the direction of local wave vector defined by ∇S_+. Polarization vector depends on E^2 position only.

2. The most general MEs correspond to the solution family of the field equations having the general form

$$s^k = f^k(S_+, E) \ ,$$

   where s^k denotes CP_2 coordinates and f^k is an arbitrary function of S_+ and E. The solution represents a wave propagating with light velocity and having definite S_+ dependent polarization in the direction of ∇E. By replacing S_+ with S_- one obtains a dual solution. Field equations are satisfied because energy momentum tensor and Kähler current are light-like so that all tensor contractions involved with the field equations vanish: the orthogonality of M^2 and E^2 is essential for the light-likeness of energy momentum tensor and Kähler current.

3. The simplest solutions of the form $S_\pm = m^0 \pm m^3$, $(E_1, E_2) = (m^1, m^2)$ and correspond to a cylindrical MEs representing waves propagating in the direction of the cylinder axis with light velocity and having polarization which depends on point (E^1, E^2) and S_+ (and thus time). For these solutions four-momentum is light-like: for more general solutions this cannot be the case. Polarization is in general case time dependent so that both linearly and circularly polarized waves are possible. If m^3 varies in a finite range of length L, then "free" solution represents geometrically a cylinder of length L moving with a light velocity. Of course, ends could be also anchored to the emitting or absorbing space-time surfaces.

4. For the general solution the cylinder is replaced by a three-dimensional family of light like curves and in this case the rectilinear motion of the ends of the cylinder is replaced with a curvilinear motion with light velocity unless the ends are anchored to emitting/absorbing space-time surfaces. The non-rotational character of the velocity flow suggests that the freely moving particle like 3-surface defined by ME cannot remain in a infinite spatial volume. The most general ansatz for MEs should be useful in the intermediate and nearby regions of a radiating object whereas in the far away region radiation solution is excepted to decompose to cylindrical ray like MEs for which the function $f(m^1, m^2, m^2)$ is a linear linear function of m^i.

3.4.2 About The Electro-Weak And Color Fields Associated WithMassless Extremals

Space-time sheets carrying em fields carry usually also Z^0 and W fields and it is not possible to speak about em or Z^0 type MEs. It is however possible to speak about neutral and W MEs. The CP_2 projection of ME is 2-dimensional and in a special case it reduces to a geodesic sphere. There are two kinds of geodesic spheres in CP_2.

1. For space-time sheets for which CP_2 projection is $r = \infty$ homologically non-trivial geodesic sphere of CP_2 one has

$$\gamma = (\frac{3}{4} - \frac{sin^2(\theta_W)}{2})Z^0 \simeq \frac{5Z^0}{8} \quad .$$

The induced W fields vanish in this case and they vanish also for all geodesic sphere obtained by $SU(3)$ rotation.

2. For homologically trivial geodesic sphere a standard representative is obtained by using for the phase angles of standard complex CP_2 coordinates constant values. In this case induced em, Z^0, and Kähler fields vanish but induced W fields are non-vanishing. This holds also for surfaces obtained by color rotation. Hence one can say that for non-vacuum extremals with 2-D CP_2 projection color rotations and weak symmetries commute.

The MEs corresponding to these two geodesic spheres could be called neutral and W MEs and they carry color fields for which the color group $SU(3)$ reduces to some of its $U(1)$ subgroups. Quite generally, the holonomy algebra of color group is Abelian since the induced color field is of the form $g^A_{\alpha\beta} \propto H^A J_{\alpha\beta}$, where H^A denotes color Hamiltonian. Neutral MEs are excellent candidates for mediating EEG type communications from the biological body to the magnetic body whereas charge entanglement induced by W MEs would be ideal for the realization of motor actions of the magnetic body.

MEs are excellent candidates for the space-time correlates of laser beams. Dark matter hierarchy implies that also MEs can be classified by the level of the dark matter hierarchy involved. Mersenne hypothesis [K37] is an explicit conjecture about the hierarchy of weak physics and their dark counterparts and allow to make explicit quantitative predictions about the role of weak interactions in living matter since as many as four Gaussian Mersennes are in the p-adic length scale range 10 nm-528 nm.

3.4.3 MEs As Absorbing And Emitting Quantum Antennae

How massless extremals generate coherent states of photons?

ME: s can be in "dormant" or active state according to whether the em current associated with the ME is vanishing or not. In active state ME: s generate Bose Einstein condensate type state for ordinary photons. This means in TGD context the emission of (topological) vapour phase photons (CP_2 type extremals), which can condense on other condensate levels. ME: s generate gravitonic BE condensate and the possible biological role of this condensate will be discussed later.

Assuming that the coupling of quantized photon field to the massless extremal is given by regarding the massless extremal as a classical background field one obtains QED with a light like source J^α:

$$\begin{aligned} D_\beta F^{\alpha\beta} &= eJ^\alpha \quad , \\ J^\alpha &= Jk^\alpha \quad . \end{aligned} \tag{3.4.2}$$

The system is equivalent with an infinite number of harmonic oscillators each driven by a harmonic external force and a basic exercise in the quantum mechanics shows that the solutions of the field equations give the new oscillator operators as sums of free oscillator operators plus c-number term, which is essentially the Fourier component of the light like current in the direction of the polarization.

In the limit that ME has infinite duration and is a cylindrical structure of finite length L (that is micro-tubule) one has for $J \propto sin(k_z(t-z))$

$$
\begin{aligned}
a^\dagger(p) &\rightarrow a^\dagger(p)+g(p) \ , \\
g(p) &= \sum_n \delta(p^0,k_n^0)K(p,k_n)J(k_n^z,p_T) \ , \\
K(p,k) &= \epsilon(p)\cdot k\frac{1}{i(p_z-k_z)}(exp(ip_zL)-1) \ , \\
k_n &= nk_0=\frac{n2\pi}{L}(1,1,0,0) \ . \qquad (3.4.3)
\end{aligned}
$$

Here p denotes the momentum of the photon and k the 4-momentum associated with the Fourier component of a light-like current. $\epsilon(p)$ denotes the polarization of the photon. $J(k_n^z,p_T)$ is essentially the 3-dimensional Fourier transform of the scalar function J. The infrared behavior of $J(k_z,p_T)$ as a function of the transversal momentum p_T can be deduced from the fact that the transverse dimension of the micro-tubule is small (about 25 nm) as compared to $1/p_T$ so that the Fourier component is in good approximation independent of p_T.

For the frequencies present in the Fourier decomposition of the massless extremal, the ordinary oscillator vacuum is transformed to a coherent state in the corresponding Fourier mode of the quantized photon field. The essential point is that the wave vectors of the radiation field and massless extremal are nonorthogonal. The radiation pattern resembles the ordinary antenna pattern associated with an oscillating current $J(t)=exp(i\omega t)$ in that the intensity of radiation vanishes at angles $\theta=\pi/2$ and $\theta=0$. For $J\propto sin(k_z(z-t))$ $|K|^2$ has maxima for $\theta=48.6$ degrees and 131.4 degrees. For an ordinary dipole with $J=sin(\omega t)$, $\omega=2\pi/L$ the radiation pattern is concentrated at angles $\theta\geq 40$ degrees with maximum and 69.3 degrees and 110.7 degrees.

A more complicated situation corresponds to a group of several massless extremals (say micro-tubules). If massless extremals are parallel and have same length the previous expression generalizes with superposition of terms

$$
g(p) \rightarrow \sum_n exp(i\phi_n)exp(ip_zz_n)exp(ip_T\cdot x_T)g_n(p) \ . \qquad (3.4.4)
$$

The phase ϕ_n is the phase difference between n: th light like current with respect to some reference current. If the positions of micro-tubules and/or phases of the individual light like currents are suitably chosen then various terms interfere constructively and macroscopic quantum coherence is obtained at resonant frequencies. Suffice it so say that the needed timing is extremely accurate: less than 10^{-12} seconds! Since p_z is small rather larger transversal distances are allowed by the requirement of constructive interference. In a more general situation also the orientations of micro-tubules can vary in certain limits. Note that light-like energy momentum generates also gravitonic BE condensates at preferred frequencies.

Massless extremal is accompanied by a Bose-Einstein condensate of parallel photons

The interaction Lagrangian describing the interaction of photon field with the light-like vacuum current does not couple to the photons collinear with the vacuum current (light-like wave vector has vanishing length squared). Therefore the ground states of the system are degenerate since one can add to any coherent state generated by the vacuum current any number of photons collinear with the vacuum current and topologically condensed inside the massless extremal. This means Bose-Einstein condensation in collinear degrees of freedom.

Collinear Bose-Einstein condensates of photons are crucial for the model of the quantum correlates of the sensory qualia. Sensory quale is characterized partially by the BE condensate of photons associated with the massless extremal parallel to the axon. The existence of the BE condensate makes possible induced emission. For instance, Josephson currents generate photons with frequencies which are multiples of the Josephson frequency. If the potential difference in Josephson junction equals to a multiple of the cyclotron frequency of some super conducting ion, the current flows resonantly in the sense that Josephson current serves as a harmonic perturbation generating quantum jumps and gives rise to a large dissipative current and also quantum jumps in either super conductor. Since the emission rate for photons by the current is proportional to N^2, where N is the number of photons already in the state, the presence of the BE condensate of photons with this frequency amplifies the emission rate. This kind of resonance mechanism is assumed in the model of sensory experience since it elegantly explains why given neuron corresponds to single quale. Since the potential difference over the Josephson junction can correspond to only single cyclotron frequency, the dominance of single quale is unavoidable even when all macroscopic quantum phases are present.

The existing BE condensate increases the probability of topological condensation of coherent photons generated by other massless extremals to the massless extremal. This mechanism could provide inter-neuronal communication mechanism and realize the metaphor about brain as a society of neutrons, the notion of neuronal window idea and also give a more precise content to the music metaphor. In particular, neurons far away from each other could communicate using wavelengths in a narrow wave length range by this mechanism.

The wave vectors of the photons are multiples of $k = \pi/L$. This means that the length of the massless extremal correlates with the maximal allowed wavelength. For ELF photons associated with EEG frequencies of order 10 Hz the length of massless extremal is of order Earth's circumference. This suggests that more general massless extremals with a topology of torus instead of linear topology could characterize the topological field quanta of ELF fields. It is however impossible to say, whether the field equations allow more general solutions resembling massless extremals.

3.4.4 Quantum Holography And Quantum Information Theory

Sokolov and collaborators [B16] have proposed a model of quantum holographic teleportation in which the *classical* photocurrents from the sender to receiver take the role of a dynamical hologram. The connection with MEs is obvious.

1. MEs are carriers of classical light-like vacuum currents (one of the basic differences between TGD and Maxwell theory). This suggests that MEs could be interpreted also as *classical* holograms, which are *dynamical* as in quantum information theory. Light-like current would be like a dynamical (four-dimensional) diffraction grating. Light-like vacuum currents and vacuum Einstein tensor generate also coherent states of photons and gravitons and MEs serve as templates for the topological condensation of photons and gravitons to the Bose-Einstein condensate of photons collinear with ME. The Bose-Einstein condensation of collinear photons and their generalizations to colored WCW photons should affect the vacuum current by adding to the reference current what might be called evoked response. This condensation process could generate conscious experience and higher level qualia. Thus it would seem that MEs have a triple role as receiving and sending quantum antennae as well as classical holograms.

2. The proposal of [B16] generalizes to the case of MEs provided one can device a method of coding quantum states of photon field to the vacuum currents. The high efficiency photodetector matrix is in which each pixel gives rise to a photocurrent [B16], is replaced with ME or set of parallel MEs. The neural window hypothesis [K84] states that neuronal axons are accompanied by parallel MEs carrying information between sensory organs and brain and various parts of brain. This is only a less standard manner to say that ME represents classical dynamical hologram. The possibility of local light-cone coordinates allows also MEs which define curved deformations of the simplest cylindrical MEs.

   The concrete realization of holographic teleportation proposed in [B16] brings strongly in mind the architecture of the visual pathways. Thus one can wonder whether brain is performing internal teleportation of photonic quantum states with spike patterns being directly coded to the pattern of the vacuum currents flowing along MEs. If spike patterns code the dynamical hologram, a surprisingly close relationship with Pribram's views about holographic brain results. Nerve pulse patterns could be seen as specifying the necessary classical aspects of the quantum teleportation (in TGD classical physics is essential part of quantum physics, rather than some effective theory).

3. Vacuum current at a 3-dimensional time-like section of ME as a function function of time defines a dynamical 3-dimensional hologram. This is consistent with the fact that our vi-

sual experience is two-dimensional: the information is always about outer boundaries of the objects of the perceptive field. The values of the vacuum current at a given point are non-deterministic which means that vacuum current is ideal for coding information. Classical data also propagate without dispersion with light velocity obeying the laws of geometric optics and MEs imply channelling so that MEs are tailor-made for classical information transfer.

4. Space-time sheets can have both positive and negative time orientations and the sign of energy depends on time orientation in TGD framework. This means that classical communication can occur both in the direction of the geometric future and past: this is essential for the classical model of the long term memories as a question communicated to the geometric past followed by answer. The dynamical nature of the holograms means that there is no need to combine 2- or 3-dimensional holograms associated with several moments of geometric time to single hologram. To remember is to perceive an object located in the geometric past. Of course, fractality might make possible temporally scaled down versions of the geometric past but the principle would remain the same.

5. Quantum hologram view suggests that the super-symplectic representations at the light-like boundaries of MEs characterized by gigantic almost-degeneracies are the real carriers of biological information. According to the general theory of qualia [K41] this information would become conscious since elementary qualia would correspond to quantum jumps for which increments of the quantum numbers correspond to the quantum numbers labelling super-symplectic generators in the complement of Cartan algebra. In this view super-conducting magnetic flux tubes could perhaps be seen as intermediate level in the control circuitry controlled by MEs and controlling atomic level.

6. This picture leaves open whether there is a level controlling the thicknesses of the magnetic flux tubes and thus also magnetic transition frequency scales, and what this level might be. The entrainment of the endogenous frequencies to exogenous frequencies [K44] explains water memory and the effects of homeopathic remedies [I31] and could make possible also endogenous NMR spectroscopy and chemical senses. The key to the puzzle might be a purely mathematical problem: how the boundary conditions at the boundaries of the magnetic flux tubes can be satisfied? It might be that the induced metric must become degenerate at the boundaries ($\sqrt{g} = 0$) implying a degeneracy of the induced metric at the boundary of the magnetic space-time sheet. This need not however mean that the M^4_+ projection of the boundary is a light-like surface: the projection could well be completely static. This supports the view that the boundaries do not carry super-symplectic representations, which are associated with the embedding space projection of the boundary rather than the boundary itself. One can imagine that ME with the same transversal section as magnetic flux tube is glued to the magnetic flux tube along this section: this kind of gluing results in a singular 4-surface analogous to the vertex region of Feynman diagram and some kind of smoothing-out procedure is needed. The smoothed-out vertex region would make possible for ME to control magnetic flux tube thickness by varying its own transversal thickness.

MEs as quantum holograms in the sense of quantum gravitation

Quantum holography principle naturally generalizes to an approximate principle expected to hold true also in non-cosmological length and time scales.

1. The most general ansatz for MEs (inspired by the quantum holographic thinking) relies on the introduction of the notion of local light-cone coordinates S_+, S_-, E_1, E_2. The gradients ∇S_+ and ∇S_- define two light-like directions just like Hamilton Jacobi functions define the direction of propagation of wave in geometric optics. The two polarization vector fields ∇E_1 and ∇E_2 are orthogonal to the direction of propagation defined by either S_+ or S_-. Since also E_1 and E_2 can be chosen to be orthogonal, the metric of M^4_+ can be written locally as $ds^2 = g_{+-}dS_+dS_- + g_{11}dE_1^2 + g_{22}dE_2^2$. In the earlier ansatz S_+ and S_- where restricted to the variables $k\cdot m$ and $\tilde{k}\cdot m$, where k and $\tilde{k}$ correspond to light-like momentum and its mirror image and m denotes linear M^4 coordinates: these MEs describe cylindrical structures with constant direction of wave propagation expected to be most important in regions faraway from the source of radiation.

2. Boundary conditions are satisfied if the 3-dimensional boundaries of MEs have one light-like direction (S_+ or S_- is constant). This means that the boundary of ME has metric dimension $d = 2$ and is characterized by an infinite-dimensional super-symplectic and super-conformal symmetries just like the boundary of the embedding space $M^4_+ \times CP_2$: The boundaries are like moments for mini big bangs (in TGD based fractal cosmology big bang is actually replaced with what might be called a silent whisper amplified to not necessarily so big bang). Quantum holography would mean that effectively 2-dimensional conformal field theory at the boundary of M^4_+ region determined by ME determines what happens in the interior at QFT limit when space-time surface is not regarded as a dynamical object.

3. These observations inspire the conjecture that boundary conditions for M^4 like space-time sheets fixed by the preferred extremal property of Kähler action quite generally require that space-time boundaries correspond to light-like 3-surfaces with metric dimension equal to $d = 2$. Quantum holography principle would state that the dynamics related to the metric of WCW , that is genuine quantum gravitation, would reduce to the boundaries of space-time sheets. The dynamics in zero modes and quaternion conformal degrees of freedom crucial for elementary particle physics would not however allow this kind of reduction. This would be consistent with the fractality which is expected to be a basic characteristic of the quantum critical Universe predicted by TGD. The approximate super-symplectic and conformal symmetries would be associated with the light-like boundaries of the space-time sheets. super-symplectic invariance would be broken only by quantum gravitational effects at the level of the configuration space by the fact that the boundaries of space-time surfaces are actually dynamical rather than fixed. The cosmological light-cone boundary would be however non-dynamical and this would guarantee the exactness of the cosmological super-symplectic invariance.

More concrete view about MEs as holograms

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3. Vacuum current at a 3-dimensional time-like section of ME as a function function of time defines a dynamical 3-dimensional hologram. This is consistent with the fact that our visual experience is two-dimensional: the information is always about outer boundaries of the objects of the perceptive field. The values of the vacuum current at a given point are non-deterministic which means that vacuum current is ideal for coding information. Classical data also propagate without dispersion with light velocity obeying the laws of geometric optics and MEs imply channelling so that MEs are tailor-made for classical information transfer.

4. Space-time sheets can have both positive and negative time orientations and the sign of energy depends on time orientation in TGD framework. This means that classical communication can occur both in the direction of the geometric future and past: this is essential for the classical model of the long term memories as a question commmunicated to the geometric past followed by answer. The dynamical nature of the holograms means that there is no need to combine 2- or 3-dimensional holograms associated with several moments of geometric time to single hologram. To remember is to perceive an object located in the geometric past. Of course, fractality might make possible temporally scaled down versions of the geometric past but the principle would remain the same.

5. Quantum hologram view suggests that the super-symplectic representations at the light-like boundaries of MEs characterized by gigantic almost-degeneracies are the real carriers of biological information. According to the general theory of qualia [K41] this information would become conscious since elementary qualia would correspond to quantum jumps for which increments of the quantum numbers correspond to the quantum numbers labelling super-symplectic generators in the complement of Cartan algebra. In this view super-conducting magnetic flux tubes could perhaps be seen as intermediate level in the control circuitry controlled by MEs and controlling atomic level.

6. This picture leaves open whether there is a level controlling the thicknesses of the magnetic flux tubes and thus also magnetic transition frequency scales, and what this level might be. The entrainment of the endogenous frequencies to exogenous frequencies explains water memory and the effects of homeopathic remedies [I31], and could make possible also endogenous NMR spectroscopy and chemical senses. The key to the puzzle might be a purely mathematical problem: how the boundary conditions at the boundaries of the magnetic flux tubes can be satisfied? It might be that the induced metric must become degenerate at the boundaries ($\sqrt{g} = 0$) implying a degeneracy of the induced metric at the boundary of the magnetic space-time sheet. This need not however mean that the M^4_+ projection of the boundary is a light-like surface: the projection could well be completely static. This supports the view that the boundaries do not carry super-symplectic representations, which are associated with the embedding space projection of the boundary rather than the boundary itself. One can imagine that ME with the same transversal section as magnetic flux tube is glued to the magnetic flux tube along this section: this kind of gluing results in a singular 4-surface analogous to the vertex region of Feynman diagram and some kind of smoothing-out procedure is needed. The smoothed-out vertex region would make possible for ME to control magnetic flux tube thickness by varying its own transversal thickness.

MEs and super-symplectic and super-conformal symmetries

TGD predicts two kinds of super-conformal symmetries [K103]. Quaternion conformal symmetries correspond to the gauge symmetries of fundamental interactions. Cosmological super-symplectic symmetries act on the boundary of light-cone and are cosmological symmetries.

The non-determinism of Kähler action however implies that the light-like M^4_+projections of light-like boundaries of MEs take the role of the boundary of future light-cone as quantum holograms and super-symplectic symmetry becomes ordinary macroscopic symmetry. Thus there is a fractal hierarchy of quantum holograms inside quantum holograms. One can identify the light-like boundaries of MEs as geometric correlates for selves. Also space-like selves are very probably needed and magnetic flux tube structures could represent them. Indeed, the non-determinism of CP_2 type extremals representing elementary particles (their M^4_+ projections are random light-like curves) makes it impossible to characterize the quantum state completely by the data on the light-like boundaries of MEs.

MEs are natural carriers of super-symplectic representations obtained by multiplying ordinary physical states by WCW Hamiltonians (functions of CP_2 coordinates and coordinates E_1, E_2 and S_+ or S_- which can obviously be arranged into irreducible representations of the color group $SU(3)$) and define an excellent candidate for a hierarchy of higher level life forms. The intuitive belief that quantum gravitation is crucial for higher level consciousness can be indeed justified in this framework: the "worlds about worlds" aspect of higher level consciousness is what requires genuine quantum gravitational states.

The boundary of ME having one light-like direction gives rise to conformal quantum hologram representing quantum correlation functions for quantum field theory defined in the interior of ME. This 3-dimensional dynamical quantum hologram should code for conscious information about external world. This information could be determined by coherent light and gravitons scattered from the outer boundaries of other space-time sheets and could provide a quantum representation for the geometry of the boundaries of the other space-time sheets.

super-symplectic degrees of freedom makes MEs ideal candidates for the correlates of higher level consciousness.

1. The states of super-symplectic representations have gigantic almost-degeneracies broken only by non-commutativity of super-symplectic and Poincare symmetries which means huge information storage capacities. super-symplectic representations can be realized in real context using Bose Einstein condensates of massless elementary particles on MEs. Super-symplectic representations correspond to genuine quantum gravitational effects since wave functionals in the space of 3-surfaces are involved and space-time ceases to be a passive arena of quantum dynamics. In fact, symplectic transformations of CP_2 are approximate symmetries of the theory broken only by classical gravitation. The notion of " WCW photon" having nontrivial dependence on WCW degrees of freedom characterized by Hamiltonian suggests strongly itself and seems to be crucial for understanding of the visual colors.

2. super-symplectic representations have universal transition frequency spectrum given as multiples of the fundamental frequency determined by the length of ME. If one assumes that MEs have lengths given by p-adic length scale hypothesis, fundamental frequencies turn out to correspond to important resonance frequencies in EEG.

For these reasons super-symplectic representations are ideal candidates for an infinite hierarchy of life forms associated with MEs. The great vision is that MEs and magnetic super-conductors associated with the magnetic flux tube structures form a fractal hierarchy interacting with the ordinary bio-matter via the classical gauge fields associated with MEs [K41, K37, K85].

The standard manner to see the evolution of organism is as an initial value problem with data given at time=constant space-like section of Minkowski space. This view is definitely wrong in TGD framework, where the classical non-determinism of Kähler action is absolutely essential for the understanding of bio-systems and consciousness. Rather, one should see the problem as a boundary value problem with data given at light-like surfaces bounding MEs analogous to light-cone boundary identifiable as the moment of big bang. This view conforms nicely with the active intentional aspects of the biological evolution: system can decide what it will be and life is more like a narrative with definite goals than random Brownian zigzag curve. The life cycle of the organism is specified by posing some requirements which it must satisfy in the form of boundary conditions and organism does it best to satisfy them.

Mechanism for generation of WCW photons

The super-symplectic representations should have some interaction mechanism with ordinary matter, if they are to be important for life. In particular, a mechanism making MEs to emit and absorb configuration space photons coupling to em charge, should exist. There are good reasons to expect that direct couplings between exotic super-symplectic states and ordinary elementary particles are very weak. The quantum number $L_0 = n$ defined by the Virasoro generator $L_0 = zd/dz$ (complex scaling) acting effectively as Hamiltonian in string diagrams is conserved in vertices. For matter representations massless ground states correspond have scaling quantum number $n = n_0$, where n_0 defines the negative value of the vacuum weight. It must be emphasized that for super-symplectic representations L_0 does not seem to allow the interpretation as mass squared operator as in the case of quaternion conformal representations. The vertices in which $L_0 = O(p^k)$ state emits ordinary particle correspond to $np^k \leftrightarrow (np^k - m_0) + (m_0)$. The intermediate state is with $L_0 = np^k - m_0$ is has ultra large scaling quantum number so that the amplitude is suppressed by a huge propagator factor. The processes involving only $L_0 = O(p^k)$ states are however not suppressed.

The interaction of the exotic super-symplectic states with the classical gauge fields associated with MEs provides a unique mechanism of "matter-mind interaction". The vanishing of the vacuum weight of Super Virasoro is very much analogous to the vanishing of the Higgs vacuum expectation value in ordinary gauge theories. Indeed, the exotic super-symplectic representations have unbroken gauge symmetries, which means that electro-weak and color interactions occur like in unconfined gauge theory without symmetry breaking. The presence of long range classical color and electro-weak gauge fields implying unbroken symmetries at classical level is important part of the story.

MEs have already at the space-time level symmetries supporting the view that super-symplectic algebra acts as isometry algebra of the WCW .

First, symplectic transformations of $E^2 \times CP_2$, where E^2 is plane orthogonal to the light-like wave vector k associated with ME, are symmetries of MEs. Also symplectic transformations made local with respect to the light-like coordinate u and coordinate variable v orthogonal to u are also symmetries.

Secondly, arbitrary dependence on the variable u is equivalent with the invariance with respect to hypercomplex analytic transformations

$$x + ey \rightarrow f(x + ey) \ ,$$

$$e^2 = 1 \ .$$

where f is arbitrary function. These transformations obey Lie-algebra which is essentially identical with the Virasoro algebra spanned by the infinitesimal holomorphic transformations.

The general interaction Hamiltonian for this interaction can be guessed by recognizing the following facts.

1. Interaction Hamiltonian should have the general current-vector potential form

$$H_{int} = \sum_D \int G^A_\mu(D) J^{A\mu}(x|D) \sqrt{g_4} d^4x \ ,$$

where sum is over the representations D of color group defined by color Hamiltonians and where $G^A(D)$ represents analog of the classical gluon field associated with a particular color representation. In the case of color octet representation $G^A_\mu(\backslash 8")$ represents classical gluon field and is simply the projection of the Killing vector field of the color isometry to the space-time surface. The obvious generalization is that also in general case the vector field defined by the color transformation defines the classical gluon field. $J^{A\mu}(x|D)$ is the local current defined as the superposition of symplectic generators continued to a function of space-time coordinates.

2. The construction of a local current defined on entire space-time surface having super-symplectic generator as conserved charge is highly nontrivial task. It should be based on the observation that for ME there is a unique decomposition of M^4 tangent space to $M^4 = M^2 \times E^2$ such that E^2 is space-like plane orthogonal to the light-like wave vector k associated with ME. Let u denote the coordinate

$$u = k \cdot m \ .$$

The task is to continue the symplectic generator localized with respect to the radial coordinate of the light-cone boundary to a function in entire M^4_+. A possible manner to do this is to multiply the generator by a plane wave

$$exp(i2\pi f(u-u_0)) \ ,$$

where u denotes the restriction of the coordinate u to the light-cone boundary

$$u_0 = u_{|\delta M^4_+} \ .$$

The task is to fix the physical identification of the ME frequency. It turns out that interpretation as energy is the most plausible identification.

It might well be that only classical color fields define interaction vertices leading to the generation of WCW photons. If this is the case the octet representation for WCW photons would have a unique role. This would explain why visual colors, which can be identified as counterparts of the charged Hamiltonians associated with WCW photons, are in a special role. Furthermore, MEs have always 2-dimensional CP_2 projection and carry classical color fields and currents restricted to $U(1)$ sub-algebra of color algebra, which need not be however color neutral. This implies that only particular WCW photon and its conjugate are emitted and that only single color is created by the BE condensation of WCW photons generated by a particular ME on other MEs.

3.4.5 MEs And Quantum Control

MEs and classical de-coherence

TGD approach inspires the idea that classical de-coherence corresponds to the decomposition of a space-time sheet carrying superposition of em fields to separate space-time sheets carrying the em fields appearing in the superposition. Since em fields live at different space-time sheets, interference effects are indeed absent which means de-coherence. A more precise and rather far reaching form of this hypothesis is that classical em field is unstable against decomposition to MEs. This mechanism allows to understand what might happen when amplitude modulated em field acts with living matter in the experiments of Blackman [J23].

The extreme nonlinearity of the dynamics of preferred extremals of Kähler action implies that ELF modulated radio frequency field induces also em field component with modulating ELF frequency. If classical de-coherence generates MEs then classical amplitude modulated em fields leads to the generation of a large number of MEs at various frequencies and directions of wave vector. For instance, modulation frequency and carrier frequency could correspond to different MEs glued to each other by "wormhole contacts". Classical de-coherence and geometrically realized Fourier analysis would be the geometric and classical counterparts for field quantization reflecting the fact that the property of being preferred extremal of Kähler action implies that space-time surfaces are analogous to Bohr orbits.

MEs and conscious holograms

The notion of conscious hologram is much more practical than the concept of quantum gravitational hologram and generalizes the notion of ordinary hologram by fusing it with the notion of self [K19]. Universe is an extremely complex fractal Feynman diagram with lines replaced by 4-dimensional space-time sheets and MEs are particular kinds of lines analogous to photon lines. These lines are like laser beams, which interfere in the vertices of the Feynman diagram: vertices correspond to material space-time sheets, atoms, molecules, ..., cells, ... The 3-D hologram vision corresponds at the level of conscious hologram stereo consciousness resulting when the mental images associated with different points of the hologram fuse to single mental image by quantum entanglement involving also the sharing of mental images.

An important piece of the picture is fact that MEs appear as pairs of high frequency and low frequency MEs. The low frequency MEs serve as correlates for remote quantum entanglement, now between different parts of brain. High frequency MEs travel like massless particles along the bridges defined by the low frequency MEs and serve as bridges between different space-time sheets at the receiving end. This induces a leakage of ions between different space-time sheets, breaking of super-conductivity and dissipative self-organization: this process which is analogous to the formation of hologram, is responsible for homeostasis and metabolism and gives rise to many-sheeted ionic flow equilibrium. Also many-sheeted lasers acting in a very wide range of frequencies become possible. The frequencies correspond to differences for the energies of ions at the space-time sheets involved. MEs parallel to axons can also act as Josephson junctions connecting space-time sheets which can correspond to different p-adic primes.

Phase conjugate laser beams have as their counterpart negative energy MEs and negative energy photons resulting in time reversal. The time reversal for the dissipation induced by super current leakage seems also to be a key mechanism of bio-control. This leads to the working hypothesis that negative energy MEs are responsible for motor control whereas positive energy MEs are involved with perception and cognition: motor action is time reversed sensory perception in appropriate p-adic time scale. Among other things negative energy MEs make possible emission of negative energies making possible buy now-pay later (or let others pay) mechanism and thus extreme flexibility of energy economy.

Many-sheeted ionic flow equilibrium controlled by MEs

A crucial empirical ingredient supporting the view about a hierarchy of magnetic super-conductors are the puzzling observations of cell biology (for a summary see the first chapter of [I63]) challenging the association of ionic channels and pumps to cell membrane. The paradoxes disappear if cell and its exterior are assumed to be in a many-sheeted ionic flow equilibrium with ionic currents flowing from super-conducting space-time sheets to atomic space-time sheets and back, so that the densities of ions at atomic space-time sheets are controlled by the very small densities and quantized currents of dark ions at super-conducting magnetic flux tube space-time sheets and coding the information about homeostasis of bio-matter [K22]. Also a reason why for liquid crystal and electret properties of bio-matter emerges and one can understand the function of electric circuitry associated with body [J15].

In this picture ionic channels and pumps would play the role of sensors detecting the concentrations of various ions and membrane voltages. The dominant part of the ionic currents would flow between cell interior and exterior as (possibly dark) supra currents and would dissipate very little. The dominant part of the metabolic energy would be used to build-up of dark EEG with photon energies above thermal threshold. Also negative dark W MEs responsible for motor actions would suck metabolic energy.

W MEs connecting magnetic body and biological body can induce charge entanglement by superposition of pairs of exotically ionized states with opposite exotic charges. State function reduction then selects either of the resulting states. Exotic ionization generates dark plasma oscillations which induce by Faraday law electric fields at the space-time sheets of the ordinary matter. The resulting ohmic currents in turn realize the control action on the ordinary matter (nerve pulse patterns, Ca^{2+} waves, etc...).

Neutral MEs can induce supra currents in super-conducting magnetic circuits by magnetic induction mechanism, serve as Josephson junctions between magnetic flux tubes, and induce magnetic quantum phase transitions. MEs can generate reference waves or their phase conjugates (time reversals) acting on lower level MEs serving as dynamical holograms. The induced coherent light pattern and its phase conjugate could act as a control command and its time reversed version. Conjugate reference waves provide an extremely simple mechanism of healing by time reversal allowing the living matter to fight against second law.

MEs could “read” DNA strand to the light-like vacuum current by moving along it and thus code DNA strand/conjugate strand to a hologram or its phase conjugate in turn acting as a control command or its time reversal. ELF MEs could do the same at the level of axons: instead of DNA sequences nerve pulse patterns would be read now. Thus living matter could be regarded as a symbiosis in which MEs control super-conducting magnetic flux tubes controlling ordinary matter at atomic space-time sheets via many-sheeted ionic flow equilibrium. DNA would represent the ROM of this system.

What makes this so interesting is that MEs are at the highest level of quantum control in the TGD based view about bio-system as a symbiosis in which MEs control super-conducting magnetic flux tubes controlling ordinary matter at atomic space-time sheets via many-sheeted ionic flow equilibrium. The coherent light pattern emitted by ME resulting from the interaction of ME with the reference wave (its phase conjugate) could act as a control command (time reversed control command) inducing process (time reversed process). Conjugate reference waves would thus provide an incredibly simple and general mechanism of healing by time reversal allowing the living matter to fight against second law. This would be like a general initiating a war by just nodding or shaking his head.

The formation of the phase conjugates could occur completely routinely and explain also why DNA appears in double strands. ME could read DNA strand to the pulse pattern of the light-like vacuum current by moving along the strand and thus code DNA strand (conjugate strand) to a hologram (its phase conjugate) in turn acting as a control command (its time reversal). ELF MEs could do the same at the level of axons: instead of DNA sequences nerve pulse patterns would be read now. DNA would clearly represent the ROM of this system. The coding of proteins would thus not be the only function related to DNA: DNA would be for the cell society what the first written laws were for human society, and the presence of the conjugate strand would make possible a systematic self repair at the cellular level by time reversal. More detailed considerations along these lines, in particular some empirical evidence for the hologrammic realization of the genetic code in terms of light-like vacuum currents, are represented in [K67].

MEs as Josephson junctions?

MEs can induce Josephson junctions between bio-structures. Since the electric field of ME is orthogonal to the direction of the propagation of vacuum current, the Josephson junction with potential difference is formed most naturally when super conductors are joined by join along boundaries bonds to ME in the direction of the electric field associated with ME. MEs can in principle be arbitrary thin so that the thickness of Josephson junction can be much smaller than the dominating wavelength of ME.

ME electric field can contain also constant component. In this case is however ME is necessary double sheeted since constant electric field is created by wormhole throats on boundaries of ME serving as effective charges. These MEs could give rise to the Josephson junctions with constant potential difference. An attractive hypothesis is that these ME pairs have opposite time orientations so that total energy of ME pair can vanish and can be created from vacuum without any energy cost. Clearly, these structures are cognitive in the strong sense of the word.

This coding of the transversal potential difference associated with ME pair to Josephson frequency is expected to be fundamental information coding mechanism in living matter. ME pair can contain also oscillating electric field over Josephson junction at magnetic or some other transition frequency so that MEs are ideal for control purposes.

MEs and the interaction of the classical em fields with bio-matter

MEs acting as Josephson junctions and containing oscillating em field at ELF frequency give rise to a harmonic perturbation inducing quantum jumps of the magnetic states of ions and explains the effect of ELF em fields on bio-matter. Also the presence of the mysterious intensity windows [J35, J20] can be understood. Josephson current paradigm allows to understand this effect if RF or MW MEs associated with the external field act as Josephson junctions.

1. The external electric field oscillating with frequency ω (now radio frequency) defines slowly varying potential difference over Josephson junction of length d acting as Josephson junction provided that the condition

$$\omega \ll \omega_J(max) = ZeV = ZeEd$$

holds true. This gives

$$d \gg \frac{\omega}{ZeE} \quad .$$

For $E \sim .1$ V/m and $\omega \sim GHz$ which are typical values used in experiments [J23], this condition gives $d \gg 10^{-6}$ meters which is satisfied if Josephson junctions have size not smaller than cell length scale.

2. For fixed length of Josephson junction amplitude window results if the maximal Josephson frequency $\omega_J(max)$ is slightly above some transition frequency since in this case the stationary maxima and minima of amplitude lead to long lasting resonant excitation of quantum transitions. Denoting the relative width of the resonance by $\Delta\omega/\omega = P$, the ratio of the time spent in resonance at $\Omega_J(max)$ to the time spent off resonance at Ω_J is of order

$$\frac{t(max)}{t} \sim \sqrt{1-\frac{\Omega_J^2}{\Omega_J^2(max)}} \times \frac{1}{\sqrt{P}} \ .$$

   For a narrow resonance width this ratio can be very large so that amplitude window results for fixed value of d.

3. Amplitude window results if there is a correlation between the thickness of ME and transversal electric field so that $\omega_J(max) = ZeEd(E)$ satisfies resonance condition for some values of E only, if any. In absence of this correlation Josephson junctions must have discrete spectrum of effective lengths for amplitude window to result.

4. For electric fields in the range .1 V/m the frequencies ω_J are above GHz for d larger than 3×10^{-5} meters and correspond to the frequencies for the conformational dynamics of proteins. There are obviously a large number of frequencies of this kind and several intensity windows. EM fields with these strengths should have special effects on living matter: it could be even that some kind of feature recognition process involving self-organization occurs at these field strengths. Note that the minimal size of Josephson junctions corresponds to the scaled up electron Compton length $L_e(173) = \sqrt{5}L(173) \simeq 1.6\times10^{-5}$ meters characterizing structures next to cells in the p-adic length scale hierarchy.

The interaction of MEs with super-conducting magnetic flux tubes

The interaction of brain with MEs could mean that the super-conducting magnetic flux tube circuitry associated with brain effectively acts as magnetometer somewhat in the same way as SQUID magnetometer measures the magnetic fields generated by brain. The resulting conceptual framework makes it easier to develop a quantum level model for the generation of nerve pulse and for the interaction of MEs and bio-super-conductors in terms of Josephson currents and super currents and relying on the notion of stochastic resonance.

Brain could measure the magnetic fields of MEs by using a mechanism which is very much like the mechanism of SQUID based magnetometers [J38] used to measure the magnetic fields induced by brain.

1. A large collecting circuit in which the magnetic field of ME generates a compensating current by the quantization of the magnetic flux might be involved.

2. The amplification of this field could be achieved if the circuit contains a part which is spiral like and contains large number of loops in a small area.

3. In the core region the current flowing in the loop gives rise to an amplified magnetic field which in turn can penetrate into a super-conductor in form of flux tubes and in multiples of flux quantum. By counting the number of flux quanta one obtains rough measure for the magnetic field. In the case of brain the quantized magnetic flux would directly affect the state of neurons and the model for the generation of nerve pulse specifies this interaction. This effect on neurons would be long lasting as compared with the short-lasting action induced by the nerve pulse patterns.

4. The deviation of the flux of the amplified magnetic field from an integer number of flux quanta could be measured by a neuronal counterpart of SQUID, which basically consists of a closed loop decomposing to two parts which are joined together by insulator so that current rapidly dissipates to a minimum value forced by the flux quantization. The current in SQUID serves as a measure for very weak magnetic fields of MEs. The non-linear dynamics of SQUID allows also stochastic resonance allowing to amplify very weak periodic signals. This measurement mechanism might be interpreted as a mechanism of interaction between super-conducting

magnetic flux tubes and neuronal circuits inducing also an interaction between MEs and neuronal circuits. One might guess that nerve pulse generation might involve this kind of mechanism: stochastic resonance seems to be indeed involved but not in this manner.

The collecting circuits for the neuronal SQUIDs could be of order body size or even larger. In [K41] I have proposed the notion of magnetic circulation analogous to blood circulation to be a basic control system in bio-systems. This circulation could be seen also as a collecting circuitry for magnetic flux amplified in brain, where amplifying and SQUID type components of the circuitry are located. Amplifying and SQUID type parts of the circuitry might be also located in other organs like heart: perhaps even muscles contain amplifying circuits and neuronal SQUIDs. One cannot exclude the possibility of much larger collecting circuits making possible the control of the organism by the higher levels of self hierarchy.

The spiral loops used in SQUIDs to amplify the magnetic field bring in mind the spiral structures associated with the self-organizing excitable media [A3]. I have proposed in [K73, K72] that spiral structures might in TGD framework correspond to magnetic or Z^0 magnetic flux tubes which enter along the first space-time sheet to the vertex of the spiral structure, flow to the second space-time sheet, and return along the spiral loop. These spiral loops could be also ionic em or Z^0 super-conductors. This kind of spiral loop might perhaps serve as an amplifier of the magnetic flux generated by the super current flowing along the loop.

Very general empirical inputs [I63] in dramatic conflict with the standard vision about what homeostasis between cell interior and exterior means, lead naturally to a model in which the interaction of MEs with neuron occurs via magnetic induction mechanism leading also to the generation of nerve pulses. The notion of flow equilibrium in the many-sheeted space-time is essentially involved. The mechanism can also involve stochastic resonance as a means of transforming the oscillatory motion of the gravitational pendulum serving as an analog system to a rotational motion. The necessary noise could correspond to the noisy part of the super current perhaps induced by the incoming nerve pulses.

Genetic code and color?

It is gradually becoming clear that the possibility of classical color gauge fields, the center of mass color degrees of freedom of space-time sheets analogous to rigid body degrees of freedom, and configuration space color might have deep implications for the understanding of living matter and consciousness. Colored MEs, or what what might be called WCW photons, are one possible candidate for colored particles involved with the realization of color vision. They might be also an essential element of bio-control using the analogs of laser beams and there phase conjugates to represent control commands and their time reversals. This raises the question whether color might relate somehow with the realization of genetic code. The following speculations are just first speculations but might help to open gates of imagination.

1. Minimal translation of the genetic code to holograms

WCW photons represent genuinely quantum gravitational states, state functionals in the "world of classical worlds", and thus they should correspond to highest level of self hierarchy and perform quantum control. Since color and polarization represented as angular momentum component in direction of ME characterize WCW dependence, they could play a fundamental role in the control mechanism and control commands represented by quantum holograms should be characterized by a collection of these quantum numbers. In particular, genetic code might be expressible in terms of these basic quantum numbers.

There is a thought provoking connection with the TGD based model of genetic code predicting entire hierarchy of genetic codes.

1. At the first interesting level one has 4 nucleotides corresponding to $2^2 = 4$ of statements consistent with given atomic statement (one bit fixed) in the set of $7 = 2^3 - 1$ statements coded by 3 bits and one statement thrown away.

2. DNA triplets correspond to the subset of $2^6 = 64$ mutually consistent statements of $2^7 - 1 = 127$ statements coded by 7 bits with one statement thrown away. At the next level one has $2^{127} - 1$ statements and the number of these prefered statements is $2^{126} = 2^{6\times 21}$. It is not an

accident that 126 decomposes into the product of numbers 6 and 21, where 21 is the number of different amino-acids with stopping sign counted formally as an amino-acid.

What makes the bell ringing is the appearance of the number $6 = 3 + 3$ primary colors and their conjugates. Could the number of nucleotides in the DNA triplet and its conjugate somehow correspond to the 3 primary colors and their complementary colors somehow? Note that also the 2-dimensional configuration spin is involved, and has two symmetry-related values J and $-J$ (WCW spin should be responsible for polarization sense). How could this correspondence be consistent with the idea about MEs generating coherent states of WCW photons having WCW color and spin and acting as control commands?

Consider first a minimal model in which, somewhat disappointingly, color is not necessarily needed.

1. The proposal of Gariaev and collaborators that DNA can be effectively regarded as a static sequence of laser mirrors [I54] suggests a concrete guess for the coding of genes to sequences of MEs. In TGD framework laser mirrors could correspond to transversal MEs associated with DNA nucleotides. The requirement that two orthogonal polarizations are possible, implies that there must be a pair of mutually orthogonal MEs associated with each nucleotide and orthogonal to the DNA strand.

2. WCW spin of ME, which is 2-dimensional spin, is either J or $-J$ so that $2 \times 2 = 4$ spin combinations $(\pm J, \pm J)$ are possible for the pair of MEs. The four nucleotides A, C, T, G naturally code for these spin configurations and the reversal of spin orientations corresponds naturally to the conjugations $A \leftrightarrow T$, $C \leftrightarrow G$ conjugations. Clearly, this model does not require color.

2. How color could emerge in the translation of the genetic code to holograms?

Color does not code for anything in the minimal model of the genetic code, and one could realize the genetic code using non-colored WCW photons having only polarization degree of freedom or even ordinary polarized coherent light. There are some motivations for color however.

Each hologrammic command should have time reversed version giving rise to the phase conjugate command. Color and spin conjugation is a very natural manner to represent this operation. The conjugate hologram is naturally associated with the conjugate DNA strand. This observation allows to considerably generalize the model by only requiring that MEs correspond to any of the six basic colors and that complementary nucleotides correspond to conjugate colors. This option raises the possibility that DNA code words, genes or some other sub-units of DNA strands could define color singlets. This would obviously provide a very elegant manner to decompose genetic text to subunits. A more general, and perhaps more plausible, manner to decompose genetic text to subunits is as tensor products of unentangled and irreducible color representations.

This option however allows the possibility that genetic codewords are self conjugate. What if one excludes this possibility? It is possible to exclude the possibility of self conjugate commands by using 3+3 decomposition of color algebra corresponding to colors and complementary colors. The pairs of MEs associated with the subsequent nucleotides could be assumed to correspond to, say, (red, blue, white) in this order so that the conjugate strand corresponds to (green, yellow, black). In fact, the ordering of the colors is not essential since spin states of MEs code for the information. At quantum level the requirement that three colors are different would boil down to the requirement that there is complete asymmetry with respect to the permutations of the colors of three parallel MEs. Note that in this case the color quantum numbers of the DNA strand or its complementary strand cannot sum up to zero.

Note that the three different colors for the subsequent nucleotides might make possible that the corresponding control commands act on different MEs, which could be MEs associated with DNA itself.

3. Color confinement and bio-control

If color is really there, it must have some crucially important function besides making it possible to define time reversals of the control commands and decomposition of DNA to unentangle linguistic subunits. A good guess is that color confinement is involved with this function very intimately. Color confinement in the length scale of DNA MEs requires color neutrality in this length scale. DNA strand and its conjugate, even triplet and its conjugate, can give rise to a color singlet state but this is not possible if only the MEs associated with DNA strand are activated. In this case color confinement requires that somewhere else another colored state is activated so that the resulting overall state is color singlet. Thus long range correlations in the length scale of MEs perhaps crucial for biological self organization are unavoidable.

The work of Gariaev and collaborators is based on effects associated with visible laser light interacting with DNA. This encourages to think that the lengths of DNA MEs should be of order $E-7-E-6$ meters. This conforms with the idea that genes should directly control the functioning of the cell or at least the cell nucleus. Note that genes might be regarded as longitudinally color entangled portions of DNA acting. WCW color entanglement in length scale of chromosome and nucleus could obviously be possible. If this picture is correct, color confinement would be much more, that an eternal nuisance of elementary particle theorist.

4. Also memetic codewords could be coded to holograms

One can imagine also the translation of the memetic code to a sequence of orthogonal ME pairs. The $6 \times 21 = 126$ bits for the maximal number of statements consistent with given atomic statement of the memetic code decompose into a sequence of 21 6-bit sequences interpreted as statements consisting of 21 words. Each 6-bit sequence consisting of three 2-bit units in turn is in one-one correspondence with a DNA triplet. Each 2-bit unit would code for WCW spins $\pm J$ for a a pair of orthogonal MEs possibly forming an antisymmetrized triplet of the basic colors. The duration of the memetic codeword corresponds to the secondary p-adic time scale $T_2(M_{127}) = .1$ seconds so that by Uncertainty Principle memetic code could imply long range color correlations in the length scale of Earth. ELF MEs propagating in phase with the nerve pulse sequence (this is essential and explains why ELF MEs must scan the cortex!) could translate the memetic codewords represented by the sequences of the cognitive neutrino pairs to quantum holograms.

3.4.6 Experimental Evidence For Mes

There is indeed evidence for the presence of MEs in bio-system. In CASYS'2000 conference Peter Marcer reviewed the work done by him in collaboration with Russian group [I54] led by Peter Gariaev providing experimental evidence for the hypothesis that DNA acts as a receiving and sending quantum antenna. What was observed that irradiation of DNA with visible laser light induced emission of coherent light with both visible and radio frequencies. The emitted radiation was also modulated in time scale of about .01 seconds. The modulation could be due to propagation of soliton sequences propagating along Josephson junction formed by the strands of DNA or due to non-propagating spatially constant Josephson current: both cases are mathematically equivalent with gravitational pendulum. Phantom DNA effect [I109] has explanation in terms of mind like space-time sheets identifiable as MEs. The experiments of Russian group replicated the observations of Poponin.

With inspiration coming from the experimental results, Gariaev has also suggested that DNA is accompanied by a sequence of some kind of laser mirrors. TGD suggests their interpretation as MEs [I54]. The assumption that each nucleotide is accompanied by an orthogonal pair of MEs (two orthogonal polarizations) allows a holographic realization of the genetic code. Four nucleotides are mapped to four pairs of values of the configuration spin $\pm J$ in the simplest realization [K41]. Color degrees of freedom would bring in the long term correlations forced by color confinement in the length scale of DNA ME, which should be of order of wavelength of visible light, and thus forcing structures of this size to behave like coherent units.

The bio-photons of Popp [I56] could correspond to coherent photons generated by MEs. Homeopathy could also have explanation in terms of MEs coding relevant frequency information to MEs about medicine, whose effect is also based on MEs [K121]. MEs would simply mimic the medicine. There are well documented effects related to the ability of water to absorb and transmit frequencies [J49]. The ability of water to absorb and transmit frequencies could rely on the generation of mind like space-time sheets, most naturally MEs, oscillating with the same frequency as stimulus. Water would form cognitive representation for the stimulus, mimic it, in terms of light-like vacuum current giving rise to classical em or Z^0 field providing hologram like representation for the stimulus.

MEs are predicted to form a scale invariant family and quite recent cosmological data provides support for MEs in cosmological(!) length scales [E11]. An intense beam of photons with energies of roughly 100 proton masses from a blazar at distance of about 10^8 light years have been observed. Blazar is so called gamma ray burster producing extremely intense energy fluxes in form of two jets. How these jets are produced is mystery of its own in standard physics. In TGD these jets correspond to the ends of cosmic string decaying like a cosmic firecracker into ordinary matter giving rise to galaxies. What makes observation "impossible" is that photons with these energies should never reach Earth but lose their energy via scattering with cosmic microwaves background. Somehow these photons are however able to defy laws of standard physics. One TGD based model for phenomenon is very simple: photons are Bose-Einstein condensed on and travel, not along material space-time sheet were energy would be rapidly lost, but along "massless extremal" (ME) of cosmic size scale. Cosmic laser beam is in question. One can also consider the possibility that the light-like vacuum current associated with cosmic ME generates the observed photons.

The general model for quantum control and coordination relies crucially on the existence of a hierarchy of superconductors associated with the self hierarchy (self defined as a quantum system able to avoid bound state entanglement with environment) controlling the ionic densities at atomic space-time sheets via many-sheeted ionic flow equilibrium and being quantum controlled with the mediation of the fractal hierarchy of MEs.

3.5 Bio-Systems As Superconductors

TGD Universe provides also the hardware for the realization of bio-system, in particular brain, as a macroscopic quantum system involving various kinds of super conductors. The essential elements are quantum criticality, spin glass analogy and generalization of the space-time concept and TGD based gauge field concept.

3.5.1 General Mechanisms For Superconductivity

The many-sheeted space-time concept (see **Fig.** `http://tgdtheory.fi/appfigures/manysheeted.jpg` or **Fig.** 9 in the appendix of this book) provides a very general mechanism of superconductivity based on the "dropping" of charged particles from atomic space-time sheets to larger space-time sheets. The first guess was that larger space-time sheets are very dry, cool and silent so that the necessary conditions for the formation of high T_c macroscopic quantum phases are met.

The possibility of large $\hbar$ quantum coherent phases makes however the assumption about thermal isolation between space-time sheets un-necessary. At larger space-time sheet the interactions of the charged particles with classical em fields generated by various wormhole contacts feeding gauge fluxes to and from the space-time sheet in question give rise to the necessary gap energy. The simplest model for Cooper pair is space-time sheet containing charged particles having attractive Coulombic interaction with the quarks and antiquarks associated with the throats of the wormhole contacts (see **Fig.** `http://tgdtheory.fi/appfigures/wormholecontact.jpg` or **Fig.** **??** in the appendix of this book).

A crucial element is quantum criticality predicting that superconductivity appears at the fluctuating boundaries of competing ordinary and large $\hbar$ phases for nuclei. This assumption predicts several anomalous phenomena such as cold fusion and nuclear transmutations. Also high T_c superfluidity of bosonic atoms dropped to space-time sheets of electronic Cooper pairs becomes possible besides ionic super conductivity. Even dark neutrino superconductivity can be considered below the weak length scale of scaled down weak bosons.

Magnetic and Z^0 magnetic flux tubes and walls are especially interesting candidates for supra current carries. In this case the Cooper pairs must have spin one and this is indeed possible for wormholy Cooper pairs. The fact that the critical magnetic (Z^0 magnetic) fields can be very weak or large values of $\hbar$ is in accordance with the idea that various almost topological quantum numbers characterizing induced magnetic fields provide a storage mechanism of bio-information.

This mechanism is extremely general and works for electrons, protons, ions and even charged molecules so that an entire zoo of high T_c bio-superconductors and super-fluids is predicted. All atoms and ions can be regarded as completely ionized Z^0 ions and also Z^0 superconductors (or super fluids) are predicted.

1. The experimental data about the effects of ELF em fields at cyclotron frequencies of various ions in Earth's magnetic field on bio-systems [J25] provide support for this scenario. Most remarkably, the cyclotron frequencies of biologically important ions correspond to the important frequencies of EEG and the time scale of nerve pulse corresponds to $n = 3$ multiple of proton cyclotron frequency so that a direct quantitative contact with brain consciousness results.

2. Electronic super conductors are of type II with defect regions being typically cylindrical: DNA sequences, proteins, microtubules, ... could provide examples of the defect regions. One ends up also with a model of high T_c super conductors in which the interaction of the electrons with wormhole BE condensate gives rise to Cooper pairs. The model explains elegantly the basic peculiar features of the high T_c superconductors.

3. Long ranged Z^0 force due to anomalous weak isospin of nuclei [K97, K38] and Z^0 charged wormholes make possible also Z^0 ionic superconductivity and even dark neutrino super conductivity. For instance, Z^0 ionic superconductivity is crucial in the model for the quantum correlate of hearing: audible frequencies are mapped to Z^0 cyclotron frequencies. Dark neutrino super conductors are of type I in the interesting length scale range and defect regions are stripe like. Besides cell and endoplasma membranes, epithelial sheets consisting of two cell layers and some larger structures in cortex could correspond to regions of this kind and the interpretation as a physical realization of cognitive hierarchy suggests itself.

3.5.2 Superconductivity At Magnetic Flux Quanta In Astrophysical-Length Scales

Magnetic flux tubes of endogenous magnetic field $B_{end} = 2B_E/5 = .2$ Gauss, where $B_E = .5$ Gauss is the nominal value of the Earth's magnetic field, are crucial for the TGD based model of superconductivity. Since the models of auroras assume that the magnetic flux lines act effectively as conducting wires, the natural hypothesis is that superconductivity is an astrophysical phenomenon. This leads to a model of auroras explaining the latest findings and providing further insights to the superconductivity and the manner how it breaks down. Critical temperature can be identified as the temperature at which the join along boundaries bonds making possible the leakage of the supra currents to the non-superconducting space-time sheets become possible and can be gigantic as compared to the temperature at the superconducting space-time sheets if space-time sheets are thermally isolated. On the other hand, the possibility of large $\hbar$ phases in principle makes possible arbitrarily high critical temperatures in a given length scale.

p-Adic length scale hierarchy and the hierarchy of dark matters labelled by values of $\hbar$ suggest the existence of an entire hierarchy of super conducting space-time sheets giving rise to a hierarchy of cognitive representations (abstractions about abstractions about...). The possibility of complex conformal weights expressible in terms of zeros of Riemann Zeta such that the net conformal weight is real, and the hierarchy of algebraic extensions of p-adic number fields suggest the existence of additional hierarchies.

3.5.3 Fractal Hierarchy Of EEGs

There are three contributions to EEG besides neural noise: Schumann frequencies, cyclotron frequencies, and the frequencies associated with Josephson junctions determined by the sum of the constant voltage and voltage perturbation determined by the superposition of cyclotron frequencies. Cyclotron contribution can be interpreted as a control signal from a magnetic body in question labelled by k_d characterizing the power of 2 defining the effective Planck constant as $h_{eff} = 2^{k_d}h$, and affects both the ions at the flux sheets traversing DNA and the Josephson junction. The coherent state of photons generated by Josephson current corresponds to a reaction to this signal received by the magnetic body as a feedback. Schumann frequencies can be assigned to the control by magnetic body of Earth and correlate with the collective aspects of consciousness.

The analysis of the Josephson current [K37] suggests the conclusion that the frequencies in the coherent state of photons are in general sums and differences of Josephson frequency and harmonics of cyclotron frequencies. For small amplitudes this implies that alpha band to which the cyclotron frequencies most biologically important bosonic ions corresponds has as satellites theta and beta bands. Higher harmonics correspond to gamma and higher bands having also satellites. For large amplitudes EEG becomes chaotic which is indeed the property of beta band during say intense concentration or anxiety. The findings of Nunez [J67] about narrow 1-2 Hz wide bands at 3, 5, 7 Hz and 13, 15, 17 Hz confirm with the prediction of satellite bands and fix the Josephson frequency to 5 Hz. This picture explains the general characteristics of EEG in wake-up state qualitatively and quantitatively.

In order to understand the characteristics during various stages of deep sleep one must assume that the cyclotron frequency scale of ions is scaled down by a factor of 1/2. One explanation is that right *resp.* left brain hemisphere corresponds to $Z = 2$ *resp.* $Z = 1$ quantization condition $Z\int BdS = n\hbar$ for the magnetic flux. $Z = 2$ case allows only doubly charged bosonic ions at magnetic flux sheets. $Z = 1$ case also also singly charged ions be their bosons or fermions and for this option magnetic field is scaled down by a factor of 1/2. The alternative explanation is that during sleep only Bose-Einstein condensates of singly charged exotic ions resulting when color bond inside nucleus becomes charged are present. This reduces the scale of cyclotron frequencies by a factor 1/2 and leaves only theta and delta bands. During stage 4 sleep only only DNA cyclotron frequencies in delta band are around 1 Hz and just above the thermal threshold are predicted to be present. For $k_d = 3$ and magnetic field scaled up by λ and flux tube area scaled down by λ^{-2} DNA frequencies are scaled up to kHz for $Z = 2$ flux quantization and might define neuronal synchronization frequencies.

The generalization of the model for EEG hierarchy to the case of ZEG is formally straightforward and cyclotron frequency spectrum is essentially the same [K37]. One can of course be very cautious since the notion of induced gauge field is far from well-understood: in particular. Z^0 ions are obtained when nuclear color bonds become charged and the combination of ordinary and exotic ionization can produce also em neutral Z^0 ions. Any atom, almost always boson, has an exotically charged counterpart with same statistics so that very rich spectrum of Bose-Einstein condensates results.

3.5.4 TGD Assigns 10 Hz Biorhythm To Electron As An Intrinsic Frequency Scale

p-Adic coupling constant evolution and origins of p-adic length scale hypothesis have remained for a long time poorly understood. The progress made in the understanding of the S-matrix of the theory (or rather, its generalizations M-matrix and U-matrix) [K28] has however changed the situation. The unexpected prediction is that zero energy ontology assigns to elementary particles macroscopic times scales. In particular, the time scale assignable to electron correspond to the fundamental biorhythm of 10 Hz.

M-matrix and coupling constant evolution

A breakthrough in the understanding of p-adic coupling constant evolution came through the understanding of S-matrix, or actually M-matrix defining entanglement coefficients between positive and negative energy parts of zero energy states in zero energy ontology [K28]. M-matrix has interpretation as a "complex square root" of density matrix and thus provides a unification of thermodynamics and quantum theory. S-matrix is analogous to the phase of Schrödinger amplitude multiplying positive and real square root of density matrix analogous to modulus of Schrödinger amplitude.

S-matrix for a CD with scale size n is given by $S(n) = S^n$, where S is the S-matrix for minimal sized CD, as one might expect from the fact that $S(n)$ is discrete counterpart for the unitary time evolution operator of quantum field theories. S-matrix at the limit of the large CD size is the counterpart of the ordinary S-matrix.

The notion of finite measurement resolution realized in terms of inclusions of von Neumann algebras allows to demonstrate that the irreducible components of M-matrix are unique and possesses huge symmetries in the sense that the hermitian elements of included factor $\mathcal{N} \subset \mathcal{M}$ defining the measurement resolution act as symmetries of M-matrix, which suggests a connection with integrable quantum field theories.

It is also possible to understand coupling constant evolution as a discretized evolution associated with time scales T_n, which come as integer multiples of a fundamental time scale: $T_n = n \times T_0$.

p-Adic length scale hypothesis allows to consider a stronger hypothesis $T_n = 2^n T_0$ and a slightly more general hypothesis $T_n = p^n T_0$, p prime. It seems that these scales are dynamically favored but that also other scales are possible. Number theoretic universality requires that renormalized coupling constants are rational or at most algebraic numbers and this is achieved by this discretization since the logarithms of discretized mass scale appearing in the expressions of renormalized coupling constants reduce to the form $log(2^n) = nlog(2)$ and with a proper choice of the coefficient of logarithm log(2) dependence disappears so that rational number results.

p-Adic coupling constant evolution

Could the time scale hierarchy $T_n = 2^n T_0$ defining hierarchy of measurement resolutions in time variable induce p-adic coupling constant evolution and explain why p-adic length scales correspond to $L_p \propto \sqrt{p}R$, $p \simeq 2^k$, R CP_2 length scale? This looks attractive but there is a problem. p-Adic length scales come as powers of $\sqrt{2}$ rather than 2 and the strongly favored values of k are primes and thus odd so that $n = k/2$ would be half odd integer. This problem can be solved.

1. The observation that the distance traveled by a Brownian particle during time t satisfies $r^2 = Dt$ suggests a solution to the problem. p-Adic thermodynamics applies because the partonic 3-surfaces X^2 are as 2-D dynamical systems random apart from light-likeness of their orbit. For CP_2 type vacuum extremals the situation reduces to that for a one-dimensional random light-like curve in M^4. The orbits of Brownian particle would now correspond to light-like geodesics γ_3 at X^3. The projection of γ_3 to a time=constant section $X^2 \subset X^3$ would define the 2-D path γ_2 of the Brownian particle. The M^4 distance r between the end points of γ_2 would be given $r^2 = Dt$. The favored values of t would correspond to $T_n = 2^n T_0$ (the full light-like geodesic). p-Adic length scales would result as $L^2(k) = DT(k) = D2^k T_0$ for $D = R^2/T_0$. Since only CP_2 scale is available as a fundamental scale, one would have $T_0 = R$ and $D = R$ and $L^2(k) = T(k)R$.

2. p-Adic primes near powers of 2 would be in preferred position. p-Adic time scale would not relate to the p-adic length scale via $T_p = L_p/c$ as assumed implicitly earlier but via $T_p = L_p^2/R_0 = \sqrt{p}L_p$, which corresponds to secondary p-adic length scale. For instance, in the case of electron with $p = M_{127}$ one would have $T_{127} = .1$ second which defines a fundamental biological rhythm. Neutrinos with mass around.1 eV would correspond to $L(169) \simeq 5$ μm (size of a small cell) and $T(169) \simeq 1. \times 10^4$ years. A deep connection between elementary particle physics and biology becomes highly suggestive.

3. In the proposed picture the p-adic prime $p \simeq 2^k$ would characterize the thermodynamics of the random motion of light-like geodesics of X^3 so that p-adic prime p would indeed be an inherent property of X^3.

4. The fundamental role of 2-adicity suggests that the fundamental coupling constant evolution and p-adic mass calculations could be formulated also in terms of 2-adic thermodynamics. With a suitable definition of the canonical identification used to map 2-adic mass squared values to real numbers this is possible, and the differences between 2-adic and p-adic thermodynamics are extremely small for large values of for $p \simeq 2^k$. 2-adic temperature must be chosen to be $T_2 = 1/k$ whereas p-adic temperature is $T_p = 1$ for fermions. If the canonical identification is defined as

$$\sum_{n\geq 0} b_n 2^n \rightarrow \sum_{m\geq 1} 2^{-m+1} \sum_{(k-1)m\leq n<km} b_n 2^n \ .$$

   It maps all 2-adic integers $n < 2^k$ to themselves and the predictions are essentially same as for p-adic thermodynamics. For large values of $p \simeq 2^k$ 2-adic real thermodynamics with $T_R = 1/k$ gives essentially the same results as the 2-adic one in the lowest order so that the interpretation in terms of effective 2-adic/p-adic topology is possible.

p-Adic length scale hypothesis and biology

The basic implication of zero energy ontology is the formula $T_2(k) = T(k) \simeq 2^{k/2}L(k)/c = L(2,k)/c$ for the secondary p-adic time scale for $p \simeq 2^k$. This would be the analog of $E = hf$ in quantum mechanics and together hierarchy of Planck constants would imply a direct connection between elementary particle physics and macroscopic physics. Especially important this connection would be in macroscopic quantum systems, say for Bose Einstein condensates of Cooper pairs, whose signature the rhythms with $T(k)$ as period would be. The presence of this kind of rhythms might even allow to deduce the existence of Bose-Einstein condensates of hitherto unknown particles.

Unfortunately, the mistake in the identification of the p-adic length scales above electron scale forces to modify the definition of $T(k)$ by introducing a $\sqrt{5+X}$ factor so that it becomes the secondary Compton time scale of electron in the p-adic length scale considered. Writing this explicitly, one has $T_e(k) \equiv T_{2,e}(k) = 2^{k-127}T_{2,e}(127) \equiv 2^{k-127}T_e(127)$. Apologies for a loose notation replacing subscript "2, e" with "e".

1. For electron secondary Compton time equal to $T_e(k) = .1$ seconds defines the fundamental $f_e = 10$ Hz bio-rhythm appearing as a peak frequency in alpha band. This could be seen as a direct evidence for a Bose-Einstein condensate of Cooper pairs of high T_c super-conductivity. That transition to "creative" states of mind involving transition to resonance in alpha band might be seen as evidence for formation of large BE condensates of electron Cooper pairs.

2. TGD based model for atomic nucleus [L3] predicts that nucleons are connected by flux tubes having at their ends light quarks and anti-quarks with masses not too far from electron mass. The corresponding p-adic frequencies $f_q = 2^k f_e$ could serve as a biological signature of exotic quarks connecting nucleons to nuclear strings. $k_q = 118$ suggested by nuclear string model would give $f_q = 2^{18} f_e = 26.2$ Hz. Schumann resonances are around 7.8, 14.3, 20.8, 27.3 and 33.8 Hz and f_q is not too far from 27.3 Hz Schumann resonance and the cyclotron frequency $f_c(^{11}B^+) = 27.3$ Hz for $B = .2$ Gauss explaining the effects of ELF em fields on vertebrate brain.

3. For a given $T_e(k)$ the harmonics of the fundamental frequency $f = 1/T(k)$ are predicted as special time scales. Also resonance like phenomena might present. In the case of cyclotron frequencies they would favor values of magnetic field for which the resonance condition is achieved. The magnetic field which in case of electron gives cyclotron frequency equal to 10 Hz is $B_e \simeq 3.03$ nT. For ion with charge Z and mass number A the magnetic field would be $B_I = \frac{A}{Z}(m_p/m_e)B_e$. The $B = .2$ Gauss magnetic field explaining the findings about effects of ELF em fields on vertebrate brain is near to B_I for ions with f_c alpha band. Hence the value of B could be understood in terms of resonance with electronic B-E condensate.

4. The hierarchy of Planck constants predicts additional time scales $T_e(k)$. The prediction depends on the strength of the additional assumptions made. One could have scales of form $nT(k)$. Integers n could correspond to ruler and compass integers expressible as products of first powers of Fermat primes and power of 2. There are only four known Fermat primes so that one has $n = 2^n \prod_i F_i$, $F_i \in \{3, 5, 17, 257, 2^{16}+1\}$. In the first approximation only 3- and 5- and 17-multiples of 2-adic length scales would result besides 2-adic length scales.

5. Mersenne primes are expected to define the most important fundamental p-adic time scales. The list of real and Gaussian (complex) Mersennes M_n possibly relevant for biology is given by n=89, 107, 113*, 127, 151*, 157*, 163*, 167* (* tells that Gaussian Mersenne is in question).

$$
\begin{array}{lllll}
n & 89 & 107 & 113 & 127 \\
f_e/Hz & 2.7\times 10^{12} & 1.0\times 10^{7} & 1.6\times 10^{5} & 10 \\
n & 151 & 157 & 163 & 167 \\
T & 19.4\ d & 3.40\ y & 218.0\ y & 3.49\times 10^{3}\ y
\end{array}
\tag{3.5.1}
$$

3.6 Many-Sheeted Space-Time, Universal Metabolic Quanta, AndPlasmoids As Primitive Life Forms

In the following the evidence for many-sheeted space-time will be discussed.

3.6.1 Evidence For Many-Sheeted Space-Time

The dropping of particle to a larger space-time sheet liberates energy which is the difference of the energies of the particle at two space-time sheets.

In many-sheeted space-time particles topologically condense at all space-time sheets having projection to given region of space-time so that this option makes sense only near the boundaries of space-time sheet of a given system. Also p-adic phase transition increasing the size of the space-time sheet could take place and the liberated energy would correspond to the reduction of zero point kinetic energy. Particles could be transferred from a portion of magnetic flux tube portion to another one with different value of magnetic field and possibly also of Planck constant h_{eff} so that cyclotron energy would be liberated. In the following only the "dropping" option is discussed.

If the interaction energy of the particle with the matter at space-time sheet can be neglected the energy is just the difference of zero point kinetic energies. This energy depends on the details of the geometry of the space-time sheet. Assuming p-adic length scale hypothesis the general formula for the zero point kinetic energy can be written as

$$E(k) = x \times E_0(k) \ \ , \ \ E_0(k) = \frac{3}{2}\frac{\pi^2}{mL^2(k)} \ \ .$$

Here x is a numerical factor taking into account the geometry of the space-time sheet and equals to $x = 1$ for cubic geometry.

The liberated zero point kinetic energy in the case that the particle drops to a space-time sheet labelled by $k_f = k + \Delta k$ with same value of x is

$$\Delta E(k, \Delta k) = x \times E_0(k) \times (1 - 2^{-\Delta k}) \ \ .$$

The transitions are seen as discrete lines for some resolution $\Delta k \leq \Delta k_{max}$. At the limit $k \to \infty$ transitions give rise to a quasi-continuous band. The photon energy for $k \to \infty$ transition is same as the energy from $k-1 \to k$ transition, which brings in additional option to the model building.

For a proton dropping from the atomic space-time sheet $k = 137$ to very large space-time sheet ($\Delta k \to \infty$) one has $\Delta E(k) = E(k) \sim x \times .5$ eV. Since the ratio of electron and proton masses is $m_p/m_e \simeq .94 \times 2^{11}$, the dropping of electron from space-time sheet $k_e = k_p + 11$ liberates zero point kinetic energy which is by is by a factor.9196 smaller. For $k_p = 137$ one would have $k_e = 148$. This energy corresponds to the metabolic energy currency of living systems and the idea is that the differences of zero point kinetic energies define universal metabolic energy currencies present already in the metabolism of pre-biotic systems. In the following fit electron's zero point kinetic energy will be taken to be $E_0(148) = .5$ eV so that for proton the zero point kinetic energy would be $E_0(137) = .544$ eV.

The hypothesis predicts the existence of anomalous lines in the spectrum of infrared photons. Also fractally scaled up and scaled down variants of these lines obtained by scaling by powers of 2 are predicted. The wavelength corresponding to.5 eV photon would be $\lambda = 2.48$ μm. These lines should be detectable both in laboratory and astrophysical systems and might even serve as a signature for a primitive metabolism. One can also consider dropping of Cooper pairs in which case zero point kinetic energy is scaled down by a factor of 1/2.

Interestingly, the spectrum of diffuse interstellar medium exhibits three poorly understood structures [I13]: Unidentified Infrared Bands (UIBs), Diffuse Interstellar Bands (DIBs) [I4], and Extended Red Emission (ERE) [I108] allowing an interpretation in terms of dropping of protons or electrons (or their Cooper pairs) to larger space-time sheets. The model also suggests the interpretation of bio-photons in terms of generalizes EREs.

Unidentified Infrared Bands

Unidentified infrared bands (UIBs) contain strong bands at $\lambda = 3.3, 6.2, 11.3$ microns [I13]. The best fit for the values of k and Δk assuming dropping of either electron or proton are given by

λ/nm	$E/.5eV$	k	Δk	$\Delta E(k,\Delta k)/E$	p/e
3300	.7515	137	$\sim\infty$	1.002	p
6200	.4000	138	3	1.067	p
11300	.2195	139	3	0.878	p
11300	.2195	139+11=150	3	1.076	e

Table 3.1: Table gives the best fit for UIBs assuming that they result from dropping of proton or electron to a larger space-time sheet and one has $E_0(148,e) = .5$ eV. The fourth column the table gives the ratio of predicted photon energy to the energy characterizing the band and assuming $x = 1$. e/p tells whether electron or proton is in question.

λ/nm	$E/.5eV$	k	Δk	$\Delta E(k,\Delta k)/E$	p/e
628.4	3.947	$135 = 3^3 \times 5$	$\sim\infty$	0.987	p
661.4	3.750	$135 + 11 = 2 \times 73$	3	0.985	e
443.0	5.598	$134 = 2 \times 67$	2	0.933	p
578.0	4.291	$135 + 11 = 2 \times 73$	$\sim\infty$	0.986	e
579.7	4.278	$135 + 11 = 2 \times 73$	$\sim\infty$	0.984	e

Table 3.2: Table gives the best fit for DIBs assuming that they result from dropping of proton or electron to a larger space-time sheet. Notations are same as in the previous table.

Table 3.1 The last row of the table gives the ratio of predicted photon energy to the energy characterizing the band and assuming $x = 1$ and $E_0(148,e) = .5$ eV. Discrepancies are below 8 per cent. Also the dropping of protonic Cooper pair from $k = 137$ space-time sheet could reproduce the line $\Delta E = .2$ eV. The fit is quite satisfactory although there is of course the uncertainty related to the geometric parameter x.

According to [I13], UIBs are detected along a large number of interstellar sight-lines covering a wide range of excitation conditions. Recent laboratory IR spectra of neutral and positively charged poly-cyclic aromatic hydrocarbons (PAHs) has been successfully used by Allamandola [I28] to model the observed UIBs. It is believed that PAHs are produced in reactions involving photosynthesis and are regarded as precedessors of biotic life [I7]. This would conform with the presence of metabolic energy quanta.

DNA sugar backbone, some amino-acids, and various hallucinogens involve 5- and 6-cycles and the proposal is that these cycles involve free electron pairs, which possess Planck constant $\hbar = n\hbar_0$, $n = 5,6$. These free electron pairs would explain the anomalous conductivity of DNA and would be an essential characteristic of living matter. The emergence of $n = 5,6$ levels could be seen as the first step in the pre-biotic evolution.

Diffuse Interstellar Bands

There are diffuse interstellar bands (DIBs) at wavelengths 578.0 and 579.7 nanometers and also at 628.4, 661.4 and 443.0 nm. The 443.0 nm DIB is particularly broad at about 1.2 nm across - typical intrinsic stellar absorption features are 0.1 nm [I13]. The following table proposes a possible identification of these lines in terms of differences of zero point kinetic energies. Also now the best fit has errors below 7 per cent.

The peak wavelengths in chlorophyll and photosynthesis are around 650 nm and 450 nm and would correspond to second and third row of the table.

The Extended Red Emission

The Extended Red Emission (ERE) [I13, I108] is a broad unstructured emission band with width about 80 nm and located between 540 and 900 nm. The large variety of peak wavelength of the band is its characteristic feature. In majority of cases the peak is observed in the range 650-750 nm but also the range 610-750 nm appears. ERE has been observed in a wide variety of dusty astronomical environments. The necessary conditions for its appearance is illumination by UV photons with energies $E \geq 7.25$ eV from source with $T \geq 10^4$ K. The position of the peak depends on the distance from the source [I108].

According to [I13] the current interpretation attributes ERE to a luminescence originating from some dust component of the ISM, powered by UV/visible photons. Various carbonaceous compounds seem to provide a good fit to the observational constraints. However, the real nature of ERE is still unknown since most candidates seem to be unable to simultaneously match the spectral distribution of ERE and the required photon conversion efficiency.

1. Consider first the band 650-750 nm appearing in the majority of cases. The most natural interpretation is that the lower end of the band corresponds to the zero point kinetic energy of electron at $k = 135 + 11 = 146 = 2 \times 73$ space-time sheet. This would mean that the lines would accumulate near 650 nm and obey the period doubling formula

$$\frac{\lambda(k) - \lambda(\infty)}{\lambda(\infty)} = \frac{2^{-k}}{1 - 2^{-k}} \quad .$$

   By the estimate of Table 2 the lower end should correspond to $\lambda = 628.4$ nm with a correction factor $x < 1$ reducing the zero point kinetic energy. The reduction would be smaller than 4 per cent. $\Delta k = 3$ transition would correspond to 744 nm quite near to the upper end of the band. For $\Delta k = 2$ transition one has $\lambda = 867$ nm not to far from the upper end 900 nm. $\Delta k = 1$ corresponds to 1.3 μm.

2. For proton with $k = 135 = 146$ the energy band would shift by the factor $2^{11} m_e/m_p \simeq 1.0874$ giving the range (598, 690) nm.

3. The variation for the position of the peak can be understood if the charged particles at the smaller space-time sheet can have excess energy liberated in the dropping to the larger space-time sheet. This excess energy would determine the position of the lower end of the band in the range $(540, 650)$ nm.

4. One should also understand the role of UV photons with energy larger than 7.25 eV. For proton the energy would be 8.76 eV. For proton the energy would be 8.76 eV. UV photon with energy $E \geq 8$ eV could kick electrons from large space-time sheets to $k = 144 = 146 - 4$ space-time sheet where they have zero point kinetic energy of 8 eV plus possible additional energy (for proton the energy would be 8.76 eV). One possibility is that these electrons drop first to $k = 145$ by the emission of ~ 4 eV UV photon and then to $k = 144$ by the emission ~ 2 eV photon corresponding to 650 nm line. The further dropping to larger space-time sheets would produce besides this line also the lines with longer wavelengths in the band.

   The energy of UV photons brings in mind the bond energy 7.36 eV of N_2 molecule and the possibility of metabolic mechanism using UV light as metabolic energy and based on the dissociation of N_2 followed by re-association liberating metabolic energy kicking protons or electrons to a smaller space-time sheet. For the $k \rightarrow k + 3$ transition of electron the energy would be 7 eV which suggests that this transition defines important metabolic energy quantum for living interstellar dust using dissociation and its reversal as basic metabolic mechanism.

3.6.2 Laboratory Evidence For Plasmoids As Life Forms

From dust to dust

The article *From Plasma crystals and helical structures towards inorganic living matter* of Tsytovich *et al* in August issue of New Journal of Physics provides new empirical support for plasmoids as living life forms. The results of article suggest that interstellar dust could behave like living matter in some respects: it could even have variant of genetic code. This is a really shattering finding and with single blow destroys the standard dogma about life as something purely chemical. It should also give also some headaches for those influental colleagues who have decided that it is necessary to accept the anthropic principle. Here is little popularization of the result.

Scientists have discovered that inorganic material can take on the characteristics of living organisms in space, a development that could transform views of alien life.

An international panel from the Russian Academy of Sciences, the Max Planck institute in Germany and the University of Sydney found that galactic dust could form spontaneously into helixes and double helixes and that the inorganic creations had memory and the power to reproduce themselves.

A similar rethinking of prospective alien life is being undertaken by the National Research Council, an advisory body to the US government. It says Nasa should start a search for what it describes as weird life - organisms that lack DNA or other molecules found in life on Earth.

The new research, to be published this week in the New Journal of Physics, found nonorganic dust, when held in the form of plasma in zero gravity, formed the helical structures found in DNA. The particles are held together by electromagnetic forces that the scientists say could contain a code comparable to the genetic information held in organic matter. It appeared that this code could be transferred to the next generation.

Professor Greg Morfill, of the Max Planck institute of extra-terrestrial physics, said:

Going by our current narrow definitions of what life is, it qualifies. The question now is to see if it can evolve to become intelligent. It's a little bit like science fiction at the moment. The potential level of complexity we are looking at is of an amoeba or a plant. I do not believe that the systems we are talking about are life as we know it. We need to define the criteria for what we think of as life much more clearly.

It may be that science is starting to study territory already explored by science fiction. The television series The X-Files, for example, has featured life in the form of a silicon-based parasitic spore. The Max Planck experiments were conducted in zero gravity conditions in Germany and on the International Space Station 200 miles above earth.

The findings have provoked speculation that the helix could be a common structure that underpins all life, organic and nonorganic.

To sum up the essentials, plasma phase is involved and the dust life is able to construct analogs of DNA double helices and this has been achieved also in laboratory. "From dust to dust" seems to have a very deep side meaning!

Here is a more quantitative summary of the results reported in [I58].

1. The scale of the dust balls seems to be few micrometers. It is essential that the system is open in the sense that there is both metabolic energy feed and continual feed of plasma to negatively charged dust particles to preserve their charges. Authors speak about effective "gravitational" instability as a mechanism leading to the formation of the helices and identify effective gravitational coupling (the formula contains a trivial typo) as a function of charge and mass of the particle plus dimensionless parameter characterizing the modification of Debye model implied by the fact that dust particles are not electrically closed systems. Authors give a long list of life-like properties possessed by the helical structures.

2. Helical structures are generated spontaneously and possess negative charges. The repulsion of the helical structures transforms to attraction at some critical distance interval due to the fact that the large electrostatic self energy depends on the distance between helices and this makes possible double helices (authors speak about over-screening in the formal model). Similar mechanism might work also in the case of ordinary DNA double helices whose stability is poorly understood since also in this case the large negative charge could be preserved by continual feed of charge.

3. The twist angle of the helix makes bifurcations as a function of radius of helix and the values of twist angle could define the letters of genetic code. Also a mechanism for how the twist angle is communicated to neighboring helix is proposed. Also dust vortices are observed and might be those which one can occasionally observe during hot summer days.

4. Authors do not mention magnetic fields but my guess is that the helical structures reflect directly the geometry of the helical magnetic flux tubes, and that dark electron pairs with large Planck constant at these tubes might be the quantal aspect of the system. These currents might relate closely to the plasma current, which charges the dust particles. Also DNA, which is insulator, is known to be able to act as conductor, and here the free electron

pairs associated with aromatic rings having $\hbar = n \times \hbar_0$, $n = 5$ or 6, could make conduction possible since their Compton size would be n-fold.

Elephant trunks in astrophysics

TGD Universe is fractal and this means that the visible structures are formed around magnetic flux quanta containing dark matter with large value of effective Planck constant h_{eff} appear in all length scales and have geometric patterns reflecting the exact discrete symmetries of dark matter acting as rotational symmetries of the field body and at the level of visible matter giving rise to broken symmetries typical for molecular structures. The helical structures found from the rings of some planets could be one example of fractal life.

For some time ago I learned about "elephant trunks" found by Hubble (I am grateful for Miika Väisälä telling about the trunks and for giving references to the papers about the finding). They appear in very wide range of length scales: at least from 1000 au to 1 pc. They are found in close connection with molecular clouds and HII regions excite by one or more young hot stars (a "metabolic connection" with the above mentioned unidentified bands and lines and PAHs present only if there is also UV source present does not look like a bad guess). In general the trunks are

Another important finding supporting TGD view about Universe which might be seen as a fractally scaled variant of above helices. pointing like fingers to the hot stars. Here is abstract of the paper by P. Carlquist, G. F. Gahm, and H. Kristen [I32].

Using the 2.6 m Nordic Optical Telescope we have observed a large number of elephant trunks in several regions. Here, we present a small selection of this material consisting of a few large, well-developed trunks, and some smaller ones. We find that: (i) the well-developed trunks are made up of dark filaments and knots which show evidence of twisted structures, (ii) the trunks are connected with essentially two filamentary legs running in V-shape, and (iii) all trunks have the maximum extinction in their heads. We advance a theory of twisted elephant trunks which is based on the presence of magnetic flux ropes in molecular clouds where hot OB stars are formed. If the rope contains a local condensation it may adopt a V-shape as the region around the hot stars expands. If, in addition, the magnetic field in the rope is sufficiently twisted, the rope may form a double helix at the apex of the V. The double helix is identified with the twisted elephant trunks. In order to illustrate the mechanisms behind the double helix we have constructed a mechanical analogy model of the magnetic flux rope in which the rope has been replaced by a bundle of elastic strings loaded by a weight. Experiments with the model clearly show that part of the bundle will transform into a double helix when the twist of the bundle is sufficiently large. We have also worked out a simple theoretical model of a mass-loaded magnetic flux rope. Numerical calculations show that a double helix will indeed form when the twist of the rope exceeds a certain critical limit. Numerical model calculations are applied to both the analogy model experiments and one of the well-developed elephant trunks. On the basis of our model we also suggest a new interpretation of the so called EGGs.

The double helix mechanism is quite general, and should be active also in other suitable environments. One such environment may be the shell of supernova remnants. Another example is the expanding bubble outlined by the North Celestial Pole Loop.

For fractally thinking physicist consisting mostly of dark matter with large Planck constant this does not leave many options: life and even intelligent life is everywhere and in all length scales. This provides also a new view about Fermi paradox.

3.6.3 Universal Metabolic Quanta

Universal energy quanta might have rather interesting implications. For instance, irradiation of cells could provide a direct metabolic mechanism when the normal metabolic machinery fails. The universal metabolic quanta should have also played a key role during pre-biotic evolution when chemical storage mechanism were absent or primitive so that energy metabolism relied on direct absorption of photons.

Direct support for universal metabolic energy quanta

There is direct support for the notion of universal energy quanta. The first support comes from the effect of low-power laser light on living matter. More than 30 years ago a method known with various names such as low-power laser therapy, biostimulation, or photobiomodulation emerged [I105] and has now a wide range of applications. The treatment can apply both non-coherent (light emitting diodes) or coherent (laser light). In the case of of non-coherent light the method applies thin structures with thickness smaller than coherence length of light so that there is no difference between non-coherent and laser light. Laser light applies to situation when both the thickness of the surface layer and structure itself in range 1 mm- 1 cm and shorter than coherence length. Often the irradiation is applied to wounds and sites of injuries, acupuncture points, and muscle trigger points. The method involves several parameters such as wavelength in the range 400-900 nm (IR and near IR light), output power (10 100 mW), continuous wave and pulsed operation modes, and pulse parameters.

1. What is known?

The article of Karu [I105] gives a good summary about what is known.

1. The action spectrum characterizes the maxima of the biological response as a function of wavelength. Action spectrum is essentially universal. For near IR and IR light the maxima of spectra are at 620, 680, 760, 820-830 nm. The spectrum continues also to visible light [I105] but I do not have access these data.

2. The action can induce both physiological and morphological changes in non-pigmental cells via absorption in mitochondria. HeNe laser ($\lambda = 632.8$ nm) can alter the firing pattern of nerves and can mimic the effect of peripheral stimulation of a behavioral reflex.

2. Biochemical approach

In [I105] the biochemical approach to the situation is discussed.

1. In standard biochemistry based approach the natural hypothesis is that the maxima correspond to some molecular absorption lines and the task is to identify the photo acceptor. The primary acceptor in IR-to red spectral region is believed to be the terminal enzyme of the respiratory chain cytochrome c oxidase located in mitochondrion but this is just an assumption.In the violet-to-blue spectral region flavoproteins (e.g. NADHdehydrogenace in the beginning of respiratory chain) are among the photo acceptors as terminal oxidases. It is known that also non-mitochondrial enhancement of cellular metabolism exist, which does not fit well with the vision about mitochondria as power plants of cell. It is believed that electronic excitation occurs and somehow leads to the biological effect.

2. The natural assumption in biochemistry framework is that the stimulation increases the effectiveness of cellular metabolism by making the utilization of oxygen more effective. The effect of the light would occur at the control level and induce secondary reactions (cellular signalling cascades or photo signal transduction and amplification) affecting eventually the gene expression.

3. Three different regulation pathways have been suggested [I105]. Since small changes in ATP level can alter cellular metabolism significantly, the obvious idea is that photoacceptor controls the level of intracellular ATP. In starving cells this looks especially attractive hypothesis. In many cases however the role of redox homeostasis is however believed to be more important than that of ATP. The second and third pathways would indeed affect cellular redox potential shifting it to more oxidized direction. The mechanism of regulation is however not understood. Hence one can say that there is no experimental proof or disproof for the standard approach.

3. TGD inspired approach

In TGD framework the first guess is that irradiation pumps directly metabolic energy to the system by kicking particles to smaller space-time sheets. This kind of direct energy feed would be natural when the cell is starving or injured so that its control mechanisms responsible for the utilization of oxygen are not working properly. For Bose-Einstein condensate of photons this effect would be especially strong being proportional to N^2 rather than N, where N is photon number.

The effect would also appear coherently in a region whose size is dictated by coherence length when the target is thick enough.

There is a simple killer test for the proposal. The predicted energies are universal in the approximation that the interactions of protons (or electrons) kicked to the smaller space-time sheets with other particles can be neglected. The precise scale of metabolic energy quanta can be fixed by using the nominal value of metabolic energy quantum.5 eV in case of proton. This predicts the following spectrum of universal energy quanta for proton and electron

$$\begin{aligned} \Delta E_{k,n}(p) &= E_0(k,p) \times (1-2^{-n}) \ , \\ E_0(k,p) &= E_0(137,p)2^{137-k} \simeq 2^{137-k} \times .5 \ eV \ . \end{aligned}$$

$$\begin{aligned} \Delta E_{k,n}(e) &= E_0(k,e) \times (1-2^{-n}) \ , \\ E_0(k,e) &= \frac{m_p}{2^{11}m_e}E_0(137,p)2^{148-k} \simeq 2^{148-k} \times .4 \ eV \ . \end{aligned}$$

k characterizes the p-adic length scale and the transition corresponds to the kicking of charged particle from space-time sheet having $k_1 = k+n$ to $k = n$.

The shortest wavelength 630 nm is rather close to the wavelength of HeNe laser and corresponds to red light with $E_0 = 2.00$ eV. Thus one would have $k = 135$ in the case of proton which corresponds to roughly one of atomic radius for ordinary value of $\hbar$. For electron one would have $k = 150$ which corresponds to $L(151)/\sqrt{2}$: $L(151) = 10$ nm corresponds to cell membrane thickness. The following equations give the energies of photons for action spectrum and predicted values in the case of proton, which provides a better fit to the data.

n	2	3	4	5
λ/nm	825	760	680	620
E_{exp}/eV	1.50	1.63	1.82	2.00
E_{pred}/eV	1.50	1.75	1.88	1.94
E_{pred}/E_{exp}	1.00	1.07	1.02	0.97

(3.6.1)

The largest error is 7 per cent and occurs for $n = 3$ transition. Other errors are below 3 per cent. Note that also in experiments of Gariaev [I54, I47] laser light consisting of 2 eV photons was used: in this case the induced radio wave photons - possibly dark photons with energy 2 eV - had positive effect on growth of potatoes.

Possible explanation for the effect of IR light on brain

The exposure of brain to IR light at wavelength of 1072 nm is known to improve learning performance and give kick start to cognitive function [I16]. The simplest explanation is that this light reloads the metabolic energy batteries of neurons by kicking electrons or protons or their Cooper pairs to larger space-time sheets. The wavelength in question is roughly one half of the wavelength associated with metabolic energy quantum with average energy.5 eV (2480 μm) assignable to the dropping of proton to a very large space-time sheet from k=137 space-time sheet or of electron from k=137+11= 148 space-time sheet. This if the electron and proton are approximated to be free particles. Energy band is in question since both the particles can have additional interaction energy.

For the kicking of electron from very large space-time sheet to $k = 147$ space-time sheet the wave length would be below 1240 nm which is more than 10 per cent longer than 1072 nm. This would suggest that the final state electron is in excited state. The surplus energy is consistent with the width about 100 nm for the UIBs. This identification - if correct - would support the view that metabolic energy quanta are universal and have preceded the evolution of the biochemical machinery associated with metabolism and that the loading of metabolic energy batteries at the fundamental level correspond to the kicking of charged particles to smaller space-time sheets.

Could UV photons have some metabolic role?

The correlation between UV photons and ERE brings in mind the vision that high temperature plasmoids are primitive life-forms possibly having universal metabolic energy quanta in UV range. One can imagine that the development of chemical energy storage mechanisms has made it possible

Δk	1	2	≥ 3	∞
$\Delta E(144,\Delta k)/eV$	4	6	≥ 7	8
λ/nm	310(UVB)	207(UVB)	≤ 177 (VUV)	155 (VUV)

Table 3.3: The lines corresponding to the dropping of electron from $k = 144$ space time sheet defining a candidate for UV light inducing generation of ERE in the interstellar dust.

Molecule	H_2	O_2	N_2	CO	NO
E_D/eV	4.48	5.08	7.37	11.11	5.2

Table 3.4: Dissociation energies of some simple molecules.

to use visible light from Sun as a source of metabolic energy and get rid of UV quanta having disastrous biological effects. Ozone layer shields out most of UV light and also air absorbs the UV light below wavelength 200 nm, which justifies the term vacuum UV (VUV) for this range.

From Table 3 one finds that $\Delta k > 2$ electronic transitions cascading to 8 eV (155 nm) by period doubling) belong to vacuum UV (VUV) absorbed by air. The lines 310 nm and 207 nm corresponding to $\Delta k = 1$ and $\Delta k = 2$ could however define frequency windows since these lines need not correspond to any atomic or molecular electronic transitions.

In the solar photosphere the temperature is about 5800 K, roughly half of the minimum temperature 10^4 K needed to generate the UV radiation inducing ERE in interstellar dust. Solar corona however has temperature of about 10^6 K, which corresponds to a thermal energy of order 100 eV and the UV radiation from corona at above mentioned discrete frequencies resulting in dropping of electrons could serve as a metabolic energy source for pre-biotics in the interstellar space. This raises obvious questions. Should the stellar sources inducing ERE possess also corona? Could 4 eV and 6 eV UV photons from the solar corona serve as a source of metabolic energy for some primitive organisms like blue algae?

A simple model for the metabolism of plasmoids

Extended Red Emissions (EREs) are associated with the interstellar dust in presence of UV light with energies above 7.25 eV and source with temperature not below 10^4 K (maximum of wave length distribution of black body radiation corresponds to the energy 4.97 eV at this temperature). This suggests that plasmoids using UV photons as metabolic energy are involved.

1. Since the bond energies of molecules vary in few eV range and their formation typically liberates photons in UV range, the natural hypothesis is that the metabolic cycle is based on the formation of some molecule liberating UV photon kicking electron/proton to a smaller space-time sheet. UV photons from energy source would in turn induce dissociation of the molecule and thus drive the process. The process as a whole would involve several p-adic length scales and several metabolic currencies.

2. This situation is of course encountered also in the ordinary biology but with highly developed sharing of labor. Biosphere would burn hydrocarbons in animal cells with carbon dioxide as the eventual outcome. Carbon dioxide would in turn be used by plants to regenerate the hydrocarbons. Note that in the recent day technology the loop is open: hydrocarbons are burned but there is no process regenerating them: perhaps photons with large Planck constant might some day used to regenerate the fuel and give rise to "living" and perhaps tidier technology.

3. It is believed that complex organic molecules like amino-acids can form in the interstellar dust and the spontaneous formation of amino-acids is known to be possible in the interstellar ice under UV radiation. Hence at least N_2 and perhaps also CO can be expected to be present. The **Table 3.4** gives dissociation energies of some simple molecules.

(a) N_2 has bond energy 7.37 eV is slightly above the UV threshold 7.26 eV for ERE, which strongly suggests that N_2 is one of the molecules involved with the metabolism of interstellar plasmoids.

(b) If ice is present then carbon monoxide CO would be an excellent candidate for a metabolic molecule since its bond energy is as high as 11.11 eV. The exceptionally large bond energy would naturally relate to the fact that carbon and oxygen are the key molecules of life.

Anomalous light phenomena as plasmoids

TGD suggests that anomalous light phenomena (ALPs, or light balls, or UFOs depending on one's tastes and assumptions) are identifiable as plasmoids behaving as primitive life forms. In the conference held in Röros Björn Gitle-Hauge told about the determination of the spectrum of visible light emitted by some light balls observed in Hessdalen [H8] ("Hessdalen phenomenon" is the term used).

1. The spectrum is a band in the interval 500-600 nm whereas the typical ERE [I108] is concentrated in the interval 650-750 nm. The peak is in the interval 540-900 nm, the width of the band is also now 100 nm, and there are no sharp peaks. Therefore the interpretation as ERE can be considered.

2. Because Hessdalen is an old mining district, authors propose that the light ball could consist of burning dust containing some metals. Author proposes that the burning of Titanium and Scandium (encountered only in Scandinavia) might provide the energy for the light ball. Sc reacts vigorously with acids and air (burning in oxygen gives Sc_2O_3 as end product). Ti burns in oxygen and is the only element that burns in nitrogen. Ti is used in fireworks since it produces spectacular fires.

   Author notices that the emission lines of N^+, Al^{++}, *resp.* Sc^+ at 528.02 nm, 528.2 nm, *resp.* 528.576 nm might contribute to the band. This might be the case but the explanation of the band solely in terms of molecular transitions is not favored by its smoothness.

3. The bond energies of TiO and TiN are 6.9 eV and 5.23 eV so that the radiation resulting in their formation is in UV range and could provide part of the metabolic energy. I do not know about bond energy of Scandium oxide.

4. TiO_2 is known to catalyze photolysis in the presence of UV light [I17, I18], which in turn is basic step in [I19] [I19], the basic step of which in TGD Universe would be the kicking of electrons/protons to smaller space-time sheets. Therefore the UV photons liberated in the formation of molecules containing Ti could catalyze photosynthesis like process.

3.6.4 Life As A Symbiosis Of Plasmoids And Biological Life

If evolution has discovered something it usually keeps it so that plasmoids and UV metabolism should be still there. This suggests that plasmoids are still in ionosphere. What could this mean? There also also other questions and I am grateful for Sampo Vesterinen for some of them. The key questions are perhaps the following ones. Do plasmoids and biological life forms live in symbiosis in some sense? If this is the case, what plasmoids can give to us and what we can give to plasmoids?

1. Magnetic bodies as quantum plasmoids and plasmoids in magnetosphere

One must make clear what one means with plasmoid. One can consider a plasma made of ordinary visible matter and also large $\hbar$ quantum plasma at magnetic bodies in a form of Bose-Einstein condensates of charged particles. The symbiosis of plasmoids and biomatter could correspond to the symbiosis of magnetic body and biological body.

One can imagine also the possibility that visible matter plasmoids and bio-matter are in symbiosis via the mediation of magnetic bodies. Note that DNA strands are negatively charged so that there is a resemblance with a plasma like state. One aspect of symbiosis would be that magnetic body would feed charged particles to DNA.

2. Some basic facts about magnetosphere

Magnetosphere would be a natural environment for plasmoid population. If one restricts plasmoids to visible matter, then ionosphere, plasma sphere and plasma sheet are the most interesting objects of interest.

1. The temperature in the highest F layer of the ionosphere (extending from 150 km to 1500 km depending on source) is about 1200-1300 K: the photon energy is about.6-.65 eV at the maximum wavelength of thermal distribution. Hence F layer plasmoids might receive metabolic energy in the form of.5 eV metabolic energy quanta via thermal photons. Self-organization occurs in transition layers and especially interesting is the transition region 85-300 km from mesosphere to ionosphere at which temperature increases 300 K to about 1200 K.

2. Inner magnetosphere is a toruslike structure whose extension varies between $4R_E$ (day side) and $8R_E$ (night side) and shielded from solar wind. In the inner magnetosphere the typical density is about 1 ion per cubic centimeter. Inner magnetosphere is bounded by a transition layer of thickness of $\sim R$ (magneto-pause). In this region the density of the ions drops rapidly.

   Inner magnetosphere contains plasma sphere whose radius varies in the range $2R_E - 4R_E$ at day side and $2R_E - 6R_E$ at night side. Plasma has a ionospheric origin. The density of the cold plasma consisting mainly of protons sphere varies in the range $10 - 10^3$ ions/cm^3, whereas the temperature is $\sim 5\times10^3$ K, which corresponds to metabolic energy quantum of.5 eV. Note however that the energy of photon at maximum of thermal distribution is about 2.5 eV which suggests 2 eV metabolic quantum.

   The cold, dense plasma of plasma sphere is frozen around magnetic flux lines which co-rotate with Earth. In TGD framework this means that flux tubes co-rotate and thus change shape. In the equitorial plane the density of the plasma sphere drops sharply down to ~ 1 ion/cm^3 at $r = 4R$. This transition region is known as a plasma pause. During magnetic storms the outer radius decreases since the pressure of the solar wind compresses the plasma sphere. The day-night variation of the shape of the plasma sphere is rather small. Within this region the magnetic field has in a reasonable approximation dipole shape with radiation belts forming an exception.

   The surface temperature of Sun is 6×10^3 K. This temperature is roughly half of the minimum temperature 10^4 K needed for EREs from interstellar dust [I108]. This corresponds to photon energy of 3 eV at the maximum of thermal distribution and cannot induce dissociation of N_2 and other simple diatomic molecules. There is also solar corona but its temperature is about 10^6 K (10^2 eV) so that the flux of thermal photons at UV energies is very low.

   Taking seriously the finding that $T \geq 10^4$K for source is necessary for EREs, one might ask whether the plasmoids at the day side are able to receive enough metabolic energy from UV radiation of Sun. If course, there is is no need to assume that dissociation of N_2 molecules is key element in metabolic mechanism. The temperatures in both F layer and plasma sphere allow kicking of protons and electrons to smaller space-time sheets and this might save the situation. Hence metabolism is not a problem for the plasmoids except perhaps during night-time when the plasma cools down somewhat.

3. The plasma sheet [K54], [F4] at the night side of Earth dark is the most prominent feature of the outer magnetosphere. It has a thickness about Earth radius R_E and extends beyond Moon's orbit (with radius 10^3R_E). The average densities of charged particles are very low and same order of magnitude as in plasma sphere: about.4-2 per cm^3 for both protons and electrons and correlates with solar wind density.

   The temperature is very high: the thermal energy of electrons is in keV range and ionic temperatures are even higher. The high temperature is due to the leakage of matter from solar wind. Note that up to the distance $d \sim 10^2R_E$ equator region of outer magnetosphere at the night side of Earth experiences a continual solar eclipse so that this region does not receive radiation energy from Sun: the high temperature of plasma sheet solves this metabolic problem.

The presence of keV photons would destroy molecules at plasma sheet and induce a high degree of ionization so that plasmoid life must be based on ions and electrons. The energy needed to kick an electron to an atomic space-time sheet is about keV from $m_e/m_p \sim 2^{-11}$: hence the dropping of electrons from atomic space-time sheets would be the natural metabolic mechanism for plasmoid life at plasma sheet.

One of the original motivations for the plasmoid hypothesis was the strange finding that plasma sheet at the equator at the dark side of Earth is highly self-organized structure and the velocity distributions of electrons present patterns like "flowers", "eyes", "butterflies" [K54].

3. What plasmoids could give to us and what we could give to plasmoids?

An attractive general motivation for the symbiosis would be that magnetic bodies would give us ability to think and we would give them ability to sense.

1. The model of cognitive representations relies on the intersections of magnetic bodies with corresponding p-adic space-time sheets possessing literally infinite size in the real sense. The larger the magnetic body, the better the representations. Magnetic bodies could thus provide us with cognitive representations and an interesting question is whether and how this relates to the strange self-organization patterns at plasma sheet.

2. We could provide for magnetic bodies sensory input and serve as their motor instruments. These magnetic bodies might be also associated with plasma sheet and the plasmoids of ionosphere and plasma sphere and could also use plasmoids of visible matter as sensory receptors and perhaps even primitive motor instruments.

One can imagine also more concrete motivations for the symbiosis.

1. Plasmoids in the day-side ionosphere could shield biosphere from UV light by "eating" the incoming UV light. Magnetic bodies could also feed negative electronic charge from the plasmoids of magnetosphere to DNA double strands.

2. Plasmoids are not in a need of metabolic energy unless it happens that the temperature in F layer cools too much during night time from $T \sim 0.12$ eV. One might imagine that plasmoids suck metabolic energy from the biosphere during sleep (say brains which remain active): this would be a possible explanation for why we sleep. One can even imagine that during sleep magnetospheric collective levels of consciousness take command and life forms in the biosphere entangle to form kind of stereo consciousness providing a collective view what is to be human, member of species, or a part of biosphere.

4. About the interpretation of bio-photons?

Also the wave lengths of bio-photons are in the range of visible photons. Their spectrum is claimed to be featureless, which would suggest that identification in terms of photons resulting in dropping of electrons and protons to larger space-time sheets might not make sense. The variation of the geometric shape of space-time sheets, the possibility of surplus energy, and the clustering of the transition lines around the lower end of wave length spectrum might however give rise to effectively featureless spectrum.

Suppose that bio-photons correspond to superposition of ERE bands and thus reflect the presence of UV energy feed. Unless biological body is not able to generate the needed UV photons, they must arrive from Sun. Bio-photons or their dark counterparts with much longer wavelengths could indeed live at the flux quanta of the magnetic bodies and observed visible bio-photons could represent some kind of leakage.

5. Gariaev's experiments

Gariaev's experiments [I47] involved the irradiation of DNA using visible laser light with photon energy 1.9595 eV. The irradiation induced emission of radio waves with same polarization with frequencies above kHz. Radio waves induced growth of potatoes. A possible interpretation is that 2 eV photons kicked electrons to a smaller space-time sheet and thus gave metabolic energy to

DNA. The radio waves possibly resulting in the dropping of electrons back to the larger space-time sheets could have consisted of dark photons with same or smaller energy and could have been used as a metabolic energy by the potatoes. That the dropping can occur to several space-time sheets would explain why several radio wave frequencies were observed. The prediction would be sum of period doubling spectra discussed earlier since sequences of droppings are possible. The radio-wave signal would result from the de-coherence of dark radio-wave photons to a bundle of ordinary radio-wave photons.

6. Earth's interior as a living system?

For years ago I developed in detail the working hypothesis that entire magnetosphere is a living system. Even Earth's interior (and also solar surface) could contain plasmoid life [**?**, K54]. The temperature below the mantle of Earth does not differ too much from the surface temperature of Sun and metabolic energy could come from the radioactive decays from the interior of Earth. There would be UV shielding by Earth: UV light has energies above 3.1 eV whereas the temperature at the mantle-core boundary is 4300 K which corresponds to energy 2.2 eV energy at the maximum of thermal distribution. Metabolic energy quantum of 2 eV would be highly suggestive and might be directly used to kick protons and electrons to smaller space-time sheet.

The metabolism would not probably involve energy quantum of.5 eV. Magnetic flux tubes could also mediate metabolic energy from the biosphere and possibly also ionosphere and the plasmoid life in question could be at an evolutionary level not tolerating UV light and involve molecules in essential manner.

3.7 Quantum Model For The Direct Currents Of Becker

Robert Becker [J15] proposed on basis of his experimental work that living matter behaves as a semiconductor in a wide range of length scales ranging from brain scale to the scale of entire body. Direct currents flowing only in preferred direction would be essential for the functioning of living manner in this framework.

One of the basic ideas of TGD inspired theory of living matter is that various currents, even ionic currents, are quantal currents. The first possibility is that they are Josephson currents associated with Josephson junctions but already this assumption more or less implies also quantal versions of direct currents.

TGD inspired model for nerve pulse assumes that ionic currents through the cell membrane are quantal currents. If they are Josephson currents, the situation is automatically stationary and dissipation is small as various anomalies suggest. One can criticize this assumption since the Compton length of ions for the ordinary value of Planck constant is so small that magnetic flux tubes carrying the current through the membrane look rather long in this length scale. Therefore either Planck constant should be rather large or one should have a non-ohmic quantum counterpart of a direct current in the case of ions and perhaps also protons in the case of neuronal membrane: electronic and perhaps also protonic currents could be still Josephson currents. This would conform with the low dissipation rate.

In the following the results related to laser induced healing, acupuncture, and DC currents are discussed first. The obvious question is whether these direct currents are actually supracurrents and whether they could be universal in living matter. A TGD inspired model for quantal direct currents is proposed and its possible implications for the model of nerve pulse are discussed.

Whether the model for quantum direct currents is consistent with the proposed vacuum extremal property of the cell membrane remains an open question but both options explain the special role of Ca^{++} currents and current of Na^{+} Cooper pairs in the generation of nerve pulse as in would take place in TGD Universe. In fact, it is not clear what one exactly means with the vacuum extremal property of cell membrane. Many-sheeted space-time (see **Fig.** `http://tgdtheory.fi/appfigures/manysheeted.jpg` or **Fig.** 9 in the appendix of this book) allows to consider space-time sheets which can be both almost vacuum extremals and far from vacuum extremals. Also space-time sheets for which Planck constant is so large that both electronic and protonic Josephson currents become possible. Various pumps and channels could actually correspond to magnetic flux tubes along which various ionic supra currents or even Josephson currents can flow. The condition that both electronic and protonic supra currents are possible in same length scale leads to the hierarchy of Planck constants coming approximately as powers of $m_p/m_e \simeq 2^{11}$ proposed originally as a general truth. Radiation at Josephson frequency serves as a signature for Josephson currents.

In the following a TGD inspired quantum model for the direct currents of Becker as direct quantum currents is developed and shown to be consistent with what is known about nerve pulse generation.

3.7.1 Connection Between Laser Induced Healing, Acupuncture, And Association Of DC Currents With The Healing Of Wounds

The findings of Robert Becker (the book "The Body Electric: Electromagnetism and the Foundation of Life" by Becker and Selden, which can be found from web (see `http://tinyurl.com/y8rbgebw`) [J15], meant a breakthrough in the development of bioelectromagnetics. One aspect of bioelectromagnetic phenomena was the discovery of Becker that DC currents and voltages play a pivotal role in various regeneration processes. Why this is the case is still poorly understood and Becker's book is a treasure trove for anyone ready to challenge existing dogmas. The general vision guiding Becker can be summarized by a citation from the introduction of the book.

Growth effects include the alteration of bone growth by electromagnetic energy, the restoration of partial limb regeneration in mammals by small direct currents, the inhibition of growth of implanted tumors by currents and fields, the effect upon cephalocaudal axis development in the regenerating flatworm in a polarity-dependent fashion by applied direct currents, and the production of morphological alterations in embryonic development by manipulation of the electrochemical species present in the environment. This partial list illustrates the great variety of known bioelectromagnetic phenomena.

The reported biological effects involve basic functions of living material that are under remarkably precise control by mechanisms which have, to date, escaped description in terms of biochemistry. This suggests that bioelectromagnetic phenomena are fundamental attributes of living things, ones that must have been present in the first living things. The traditional approach to biogenesis postulates that life began in an aqueous environment, with the development of complex molecules and their subsequent sequestration from the environment by membranous structures. The solid-state approach proposes an origin in complex crystalline structures that possess such properties as semiconductivity, photoconductivity, and piezoelectricity. All of the reported effects of electromagnetic forces seem to lend support to the latter hypothesis.

Observations relating to CNS

The following more quantitative findings, many of them due to Becker, are of special interest as one tries to understand the role of DC currents in TGD framework.

1. CNS and the rest of perineural tissue (tissue surrounding neurons including also glial cells) form a dipole-like structure with neural system in positive potential and perineural tissue in negative potential. There is also an electric field along the neuron in the direction of nerve pulse propagation (dendrites correspond to - and axon to +) (note that motor nerves and sensory nerves form a closed loop). Also microtubules within axon carry electric field and these fields are probably closely related by the many-sheeted variants of Gauss's and Faraday's laws implying that voltages along two different space-time sheets in contact at two points are the same in a static situation.

2. A longitudinal potential along front to back in the brain with the frontal lobes in negative potential with respect to occipital lobes and with a magnitude of few mV was discovered. The strength of the electric field correlates with the level of consciousness. As the potential becomes weaker and changes sign, consciousness is lost. Libet and Gerard observed traveling waves of potentials across the cortical layers (with speeds of about 6 m/s: TGD inspired model of nerve pulse predicts this kind of waves [K82]). Propagating potentials were also discovered in glial cells. The interpretation was in terms of electrical currents.

3. It was found that brain injury generated positive polarization so that the neurons ceased to function in an area much larger than the area of injury. Negative shifts of neuronal potentials were associated with incoming sensory stimuli and motor activity whereas sleep

was associated with a positive shift. Very small voltages and currents could modulate the firing of neurons without affecting the resting potential. The "generating" potentials in sensory receptors inducing nerve pulse were found to be graded and non-propagating and the sign of the generating potential correlated with sensory input (say increase/reduction of pressure). Standard wisdom about cell membrane has difficulties in explaining these findings.

4. The natural hypothesis was that these electric fields are accompanied by DC currents. There are several experimental demonstrations for this. For instance, the deflection of assumed DC currents by an external magnetic field (Hall effect) was shown to lead to a loss of consciousness.

Observations relating to regeneration

The second class of experiments used artificial electrical currents to enhance regeneration of body parts. These currents are nowadays used in clinical practice to induce healing or retard tumor growth. Note that tissue regeneration is a genuine regeneration of an entire part of the organism rather than mere simple cell replication. Salamander limb generation is one of the most studied examples. Spontaneous regeneration becomes rare at higher evolutionary levels and for humans it occurs spontaneously only in the fractures of long bones.

1. An interesting series of experiments on Planaria, a species of simple flatworm with a primitive nervous system and simple head-to-tail axis of organization, was carried out. Electrical measurements indicated a simple head-tail dipole field. The animal had remarkable regenerative powers; it could be cut transversely into a number of segments, all of which would regenerate a new total organism. The original head-tail axis was preserved in each regenerate, with that portion nearest the original head end becoming the head of the new organism. The hypothesis was that the original head-tail electrical vector persisted in the cut segments and provided the morphological information for the regenerate. The prediction was that the reversal of the electrical gradient by exposing the cut surface to an external current source of proper orientation should produce some reversal of the head-tail gradient in the regenerate. While performing the experiment it was found found that as the current levels were increased the first response was to form a head at each end of the regenerating segment. With still further increases in the current the expected reversal of the head-tail gradient did occur, indicating that the electrical gradient which naturally existed in these animals was capable of transmitting morphological information.

2. Tissue regeneration occurs only if some minimum amount of neural tissue is present suggesting that CNS plays a role in the process although the usual neural activity is absent. The repeated needling of the stump had positive effect on regeneration and the DC current was found to be proportional to innervation. Hence needling seems to stimulate innervation or at least inducing formation of DC currents. Something like this might occur also in the case of acupuncture.

3. Regeneration involves de-differentiation of cells to form a blastema from which the regenerated tissue is formed. Quite early it was learned that carcinogens induce de-differentiation of cells because of their steric properties and by making electron transfer possible and that denervation induces tumor formation. From these findings Becker concluded that the formation of blastema could be a relatively simple process analogous to tumor growth whereas the regeneration proper is a complex self-organization process during which the control by signals from CNS are necessary and possibly realized in terms of potential waves.

4. Regeneration is possible in salamanders but not in frogs. This motivated Becker and collaborators to compare these situations. In an amputated leg of both salamander and frog the original negative potential of approximately -1 mV was raised first to a positive value of about +10 mV. In the frog it returned smoothly to its original value without regeneration. In the salamander it returned over a period of three days to the original base line and then went to a much higher negative value around -20 mV (resting potential is around -70 mV) followed by a return to the original value once regeneration had occurred. Thus the large negative potential is necessary for the regeneration and responsible for the formation

of blastema. Furthermore, artificial electron current also induced regeneration also in the case of the frog, even in the denervated situation. Thus the flow of electrons to the stump seems to be necessary for the formation of blastema and the difference between salamander and frog is that frog is not able to provide the needed electronic current although positive potential is present.

5. It was also learned that a so called neuroepidermal junction (NEJ) formed in the healing process of salamander stump was responsible for the regeneration in the presence of denervation. The conclusion was that the DC voltage and electronic current relevant for regeneration could be assigned the interface between CNS and tissue rather than to the entire nerve and the regeneration seemed to be a local process, perhaps a feed of metabolic energy driving self-organization. Furthermore, NEJ seemed to make possible the flow of electrons from CNS to the stump.

6. The red blood cells of animals other than mammals are complete and thus possess nuclei. Becker and collaborators observed that red blood cells also dedifferentiated to form blastemas. Being normally in a quiescent state, they are ideal for studying de-differentiation. It was found that the electric current acted as a trigger at the level of cell membrane inducing de-differentiation reflected as an increased amount of mRNA serving as marker of gene expression. Also pulsed magnetic field was found to trigger the de-differentiation, perhaps via induced electric field. By the way, the role of the cell membrane fits nicely with the TGD inspired view about DNA-cell membrane system as topological quantum computer with magnetic flux tubes that are assumed to connect DNA and cell membrane and serve as braid strands in TGD inspired model of DNA as topological quantum computer [K5].

7. The experiments of Becker and collaborators support the identification of the charge carriers of DC currents responsible for the formation of the stump's large negative potential as electrons. The test was based on the different temperature dependence of electronic and protonic conductivities. Electronic conductivity increases with temperature and protonic conductivity decreases and an increase was observed.

Gene activation by electrostatic fields?

The basic question concerns the method of activation. The discovery of chemists Guido Ebner and Guido Schuerch [J5] raises the hope that these ideas might be more than over-active imagination and their work also provides a concrete proposal for the activation mechanism. Ebner and Schuerch studied the effect of electrostatic fields on the growth and morphogenesis of various organisms. Germ, seeds, or eggs were placed between conducting plates creating an electric field in the range.5-2 kV/m: note that the Earth's electric field is in the range $.1-4$ kV/m and of the same order of magnitude.

The outcome was rather surprising and in the year 1989 their employer Ciba Geigy (now Novartis) applied for a patent "Method of enhanced fish breeding" [J5] for what is called Ciba Geigy effect. The researchers describe how fishes (trouts) develop and grow much better, if their eggs have been conditioned in an electrostatic field. The researchers also reporedt [J5] that the morphology of the fishes was altered to what seems to represent an ancient evolutionary form: this was not mentioned in the patent.

The chemists founded their own Institute of Pharmaceutical Research near Basel, where Guido Ebner applied for another very detailed patent, which was never granted. In the patent he describes the effect of electrostatic fields on several life forms (cress, wheat, corn, fern, micro-organisms, bacteria) in their early stage of development. A clear change in the morphogenesis was observed. For instance, in one example fern had all sort of leaves in single plant apparently providing a series of snapshots about the evolution of the plant. The evolutionary age of the first leaf appeared to be about 300 million years whereas the last grown-up leaf looked close to its recent form.

If one takes these finding seriously, one must consider the possibility that the exposure to an electrostatic field can activate passive genes and change the gene expression so that older morphologies are expressed. The activation of not yet existing morphologies is probably more difficult since strong consistency conditions must be satisfied (activation of program requires activation of a proper hardware). This would suggest that genome is a kind of archive also containing also older genomes even potential genomes or that topological quantum computer programs [K5] determine the morphology to a certain extent and that external conditions such as electric fields determine the self-organization patterns characterizing these programs.

It is known that the developing embryo has an electric field along the head-tail axis and that this field plays an important role in the control of growth. These fields are much weaker than the fields used in the experiment. p-Adic length scale hierarchy however predicts an entire hierarchy of electric fields and living matter is indeed known to be full of electret structures. The strength of the electric field in some p-adic length scale related to DNA might somehow serve as the selector of the evolutionary age. The recapitulation of phylogeny during ontogeny could mean a gradual shift of the activated part of both genome and "memone" (as as menetic analog of genome: for a proposal of memetic code see [K43]), perhaps assignable to topological quantum computer programs realized as braidings, and be controlled by the gradually evolving electric field strength.

The finding that led Ebner to his discovery was that it was possible to "wake up" ancient bacteria by an exposure to an electrostatic field. The interpretation would be in terms of loading of metabolic batteries. This would also suggest that in the case of primitive life forms like bacteria the electric field of the Earth has served as metabolic energy source whereas in higher life forms endogenous electric fields have taken the role of Earth's electric field.

A TGD based model for the situation

On the basis of these observations one can try to develop a unified view about the effects of laser light, acupuncture, and DC currents. It is perhaps appropriate to start with the following - somewhat leading - questions inspired by a strong background prejudice that the healing process - with control signals from CNS included - utilises the loading of many-sheeted metabolic batteries by supra currents as a basic mechanism.

The first series questions, observations, and ideas relates to the connection of DC currents with metabolism and ordinary biochemistry. The hierarchy of Planck constant is expected to be involved somehow.

1. How the DC currents relate to metabolism and ordinary biochemistry? For what purpose they are needed? The crucial point is that the energy of order 1 meV gained by electron in the electric field is much below the metabolic energy quantum and also thermal energy so that the interpretation in terms of metabolic energy quantum does not look promising. This forces to consider the possibility that the basic role of electric field is to drive electrons to where they are needed, say wounded part of tissue in positive potential and thus attrracting electrons. Electrons are indeed needed by the electron transport cycle appearing in both photosynthesis and cell respiration since the transport cycle induces leakage of electrons due to the formation of ROS (reactive oxygen species) such as O_2^-. The purpose of electronic Becker currents would be therefore the re-establishment of metabolism.

   The change of the sign of the Becker potential to positive induce a loss of electrons and reduced metabolism. This could explain why consciousness is lost when the sign of Becker potential is changed or electrons are deviated by Hall effect. Wound damages the connections of the tissue to the organism and the transfer of electrons compensating for leaked electrons is prevented since Becker potential changes sign. The regeneration induced by an artificial Becker potential of correct sign would induce healing by re-establishing the electron feed.

The crucial question concerns the role of electrons. It seems that in all situations electron flow to the damaged tissue induces healing. Why electrons generating negative potential should help in healing? The first input is TGD model [K77] [L15] for the findings of Pollack [L15] involves the connection of dark matter hierarchy $h_{eff} = n \times h$ with negentropic entanglement characterized by density matrix reducing to $n \times n$ unit matrix for entanglement matrix proportional to a unitary matrix. In infinite-dimensional case the divisor is infinite unless one uses von Neumann's hyperfinite factor of type II_1 for which the normalization factor can be taken to be unity: in the case of quantum groups this corresponds to using quantum trace instead of the ordinary one. A further input is the observation that the gravitational Planck constant h_{gr} explaining planetary Bohr quantization rules can be equal to h_{eff} in living matter for microscopic systems like elementary particles, atoms, and ions, even molecules [K98, K80].

1. Pollack's findings about fourth phase of water formed when external energy feed induces formation of negatively charged exclusion zones of water obeying stoichiometry $H_{1.5}O$ with 1/4: th of protons going to the complement of exclusion zone. Something similar might happen also now.

2. In TGD framework this process is explained as a formation dark phase of protons at the magnetic flux tubes associated with the exclusion zone with dark protons realizing genetic code so that one obtains what might be regarded as primitive primordial life form.

3. There is evidence for a huge anomalous gravimagnetic Thomson field in rotating super conductors. Thomson field is proportional to square of Planck constant h_{eff} and TGD explanation is that large h_{gr} phase is formed at gravitational flux tubes. The assumption $h_{gr} = h_{eff}$ in elementary particle and atomic scales is possible and is consistent with the hypothesis that bio-photons in visible and UV energy range correspond to decay products of dark EEG photons.

4. $\hbar_{gr}$ can be generalized to $\hbar_{em} = -Z_1 Z_2 e^2/v_0$: v_0 would be typical rotational velocity in a system with opposite charges Z_1 and Z_2. Exclusion zone would be good example. For ATP v_0 would be rotational velocity of ATP. For exclusion zone v_0 could be rotational velocity of Cooper pairs in magnetic field associated with flux tubes or walls or rotational velocity of magnetic body. $Z_2 = -Z_1$ is natural assumption by charge neutrality.

5. In this framework the feed of electrons would increase the value of h_{eff} by increasing the negative charge associated with the analog of exclusion zone accompanying the wound and induce also a flow of dark protons to the magnetic flux tubes associated with the magnetic body of the analog of exclusion zone.

6. The DC currents would be needed because the damage of the tissue means that the $\hbar_{eff} = \hbar_{em} = Z^2 e^2/v_0$ is reduced for a pair formed by damaged system and its complement. Healing would be essentially attempt to increase h_{eff} to its original value. The parameter Z^2 is reduced and must be increased to its original value and perhaps even to a higher value since the larger ger the value of h_{eff} is, the richer the negentropic resources of system are. The transfer of electrons to the system analogous to exclusion zone induces transfer of dark protons to the magnetic flux quanta of the magnetic body of the system. Recall that dark proton strings at flux tubes could be analogs of dark nuclei and that the model for dark nucleons allows to identify nucleon states as counterparts of DNA, RNA, amino-acids and even tRNA. This leads to a model of prebiotic lifeforms [K44].

7. ATP synthase transforming ADP to ATP involves rotating shaft and one can ask whether the velocity parameter v_0 appearing in the expression for $\hbar_{em}$ equals to the rotation speed of the shaft. This predicts that the value of $\hbar_{em}$ to be same order as $\hbar_{eff}$ and $\hbar_{gr}$ for Earth-electron system assuming that v_0 corresponds to the rotation velocity at the surface of Earth. The assumption $h_{eff} = h_{gr} = h_{em}$ makes it possible for the gravitational and em flux tubes to reconnect.

8. The original guess was that electrons to provide energy giving rise to the formation of ATP in cell respiration and photosynthesis. Electrons themselves receive their energy either from the oxidation of molecules or from solar photons. This model is consistent with the model above since electron transport chain is crucial for cell transpiration and needs both electrons and dark protons located at the dark flux tubes associated with the exclusion zones. Dark protons would flow through the ATP synthase attached to mitochodrial membrane and liberate dark cyclotron energy if the value of the magnetic fields associated with the flux tube is different for the interior and exterior portions of the flux tube [K37, K76].

The experimental support for the role of bio-photons in living matter is accumulating and a natural question concerns their role in metabolism. In TGD framework dark photons with large value of $\hbar_{eff}$ with energy of visible photon can transform to ordinary photons of same energy with some - presumably rather small - probability, and would be interpreted as bio-photons. Could dark photons take the role of solar photons and provide in some situations energy to the electrons in the electron transport cycle? This would mean a non-conventional non-local mechanism of metabolism. The effects of laser light on tissue suggest that laser light indeed takes the role of solar light and feed energy to the electron transport cycle transforming it to the energy of high energy phosphate bond of ATP. A more detailed TGD inspired view about what might happen is discussed in [K50].

One can consider also the possibility that quantum credit card mechanism (remote metabolism) could be at work in some the situations when chemical metabolic energy sources are absent. Damaged tissue might define this kind of exceptional situation. This brings in mind the strange ability of plants suffering under-nutrition to attract insects responsible for their pollination observed by Callahan, who has also reported that plants and insects communicate using infrared light which according to his findings serves as a sensor input in insect olfaction [I23]: also in this case quantum credit card mechanism building magnetic flux tube bridges guiding the insects to the plant might be at work. The electrons which have gained 1 meV energy during travel along pairs formed by MEs and parallel magnetic flux tubes (meridians), could send negative energy dark photons with energy of order -.5 eV to gain same positive energy allowing to get over the semiconductor junction after they have arrived to the damaged tissue. These negative energy photons would be absorbed by a metabolic energy store (ATP in mitochondria transforming to ADP) in the healthy part of the organism.

$h_{eff} = h_{em}$ implies that the spectrum of bio-photons originating from dark cyclotron photons is universal having no dependence on ion mass and in visible and UV range, which is also the range for molecular excitation energies. Dark cyclotron photons decaying to bio-photons would therefore allow magnetic body to control biochemistry by resonant absorption inducing transitions of molecules.

The original model for the charging of the metabolic batteries and for effective semiconductor junction assumed that the electrons of supra current are transferred to smaller space-time sheets.

1. For ground state electrons this requires energy which is at least the difference of zero point kinetic energies of electron at the two space-time sheets. This energy should be of the order of fundamental metabolic energy quantum of about.5 eV.

   For Cooper pairs of electrons the sheet should correspond to p-adic length scale of order $L_e(k_e = 149) = 10$ nm, the thickness of lipid layer of cell membrane. For single proton corresponding scale would be $L_e(k_p = 139) \simeq 2^{-12}L_e(151)$ from $m_p/2m_e \simeq 2^{10}$ and $E_{0,p}/E_{0,2e} = (2m_e/m_p) \times (L_e(k_e)/L_e(k_p))^2 = (2m_e/m_p) \times 2^{k_e-k_p} \sim 1$.

   This suggests that electron Cooper pair is kicked to a smaller space-time sheet assignable to a mitochondrial lipid layer having $k_e = 149$. The larger space-time sheet could be that of cell membrane with $k = 151$. For protons the zero point kinetic energies at these space-time sheets are by a factor $2m_e/m_p$ lower and of the order of .5 meV. This happens to be of the same order of magnitude as the energy gained by proton or electron in the Becker potential. May be this is not an accident.

   There is also a second intriguing quantitative co-incidence. In the absence of an action potential, acetylcholine vesicles spontaneously leak into the synaptic junction and cause very small de-polarizations in the postsynaptic membrane known as miniature end plate potentials (see `http://tinyurl.com/y98zhxzh`) (mEPSP) of magnitude .5 mV. These potentials are too small to generate action potential but together they can sum up to the needed action potential. Maybe the interpretation in terms of proton kicked to lipid layer space-time sheet might make sense.

2. The re-charging mechanism should relate directly to ADP→ ATP process occurring during electronic transport cycle in mitochondrial membrane. The connection with metabolism forces to ask how the formation of high energy phosphate bond in the addition of phosphate to ADP relates to the transfer of electrons to smaller space-time sheet. Somehow the energy of electrons must go to the formation of this bond: perhaps the dropping of electron back to larger space-time sheet transfers the energy to the high energy phosphate bond.

   In many-sheeted space-time particles topologically condense at all space-time sheets having projection to given region of space-time so that this option makes sense only near the boundaries of space-time sheet of a given system. Also p-adic phase transition increasing the size of the space-time sheet could take place and the liberated energy would correspond to the reduction of zero point kinetic energy. Particles could be transferred from a portion of magnetic flux tube portion to another one with different value of magnetic field and possibly also of Planck constant h_{eff} so that cyclotron energy would be liberated.

3. The transfer of particles between space-time sheets with different p-adic length scales is not the only one that one can consider, and recently a more elegant mechanism has emerged [K50]. If the particles are free, a phase transition in which the p-adic prime of the space-time sheet containing particles decreases adiabatically increases the scale of kinetic energy but leaves particle quantum numbers unchanged. If the same happens for charge particles at magnetic flux tubes, similar increase of cyclotron energy scale takes place since magnetic field strength increase to conserve magnetic flux. The predictions are in good approximation the same as for the original model. If the phase transition reducing p-adic length scale is accompanied by a compensating increase of Planck constant, the size scale of space-time sheet remains unaffected but metabolic batteries are loaded. The reversal of this phase transition liberates metabolic energy. What is important that metabolic energy and negentropic entanglement (measured in terms of the value of Planck constant) are closely correlated for this mechanism. The loading/liberation of energy is also a quantum coherent process.

4. Acupuncture and the application of DC current are known to induce the generation of endorphins. Do endorphins contribute to well-being by reducing the pain? In TGD framework the deeper level interpretation of metabolism is as a provider of negentropic entanglement in turn giving rise to well-being. Are endorphins kind of negentropy packets or just conscious signals about the improved situation?

Second series of questions, observations, and ideas relates to the meridians, acu points, and "chi".

1. A permanent potential difference of same sign between head and tail could mean an accumulation of positive and negative charges to the ends of the of the system if only electron currents are present. If both electron and proton currents with opposite directions are present, there is no accumulation of charge but there is an accumulation of protons and electrons. Probably there exists a pumping mechanism forcing the electrons (and possibly also protons) to move against the potential gradient from the tail back to the head. This however requires metabolic energy and the simplest source of this energy would be just the energy of electrons otherwise used to generate ATP. If so, the leakage would not be an unavoidable dissipative effect but a way to avoid charge accumulation.

   If the pumping mechanism is not at work, this situation cannot continue for ever and the sign of the potential difference must eventually change and induce loss of consciousness. The simplest possibility is that the potential difference changes sign rhythmically. A natural question is whether the sleep-awake rhythm is unavoidable and corresponds to the oscillatory behavior of the head-to-tail voltage.

   "Chi" would correspond electrons or their Cooper pairs in this picture. Abnormal chi flow (reduced flow, flow in wrong direction, accumulation of chi) would cause various problems including also insomnia in which too much electron charge tends to accumulate.

3. What is the nature of acupuncture meridians, what kind of currents flow along them, and why are they not directly observed? The most natural identification in TGD Universe would be in terms of magnetic flux tubes accompanied by parallel massless extremals (MEs) making possible also the propagation of dark photons used for control purposes and perhaps even in metabolism as already discussed. Dark currents along pairs of MEs and magnetic flux tubes are ideal for the transfoer of particles and energy.

   If the length of the superconducting "wire" is long in the scale defined by the appropriate quantum scale proportional to $\hbar$, the classical picture makes sense and charge carriers can be said to accelerate and gain energy ZeV. For large values of $\hbar_{eff}$ an oscillating Josephson current would be in question. Since Becker currents are associated with CNS, it would be natural to associate the meridians with neural pathways although this assignment is not necessary. Magnetic flux tube system defined kind of magnetic circulation which could serve as a template for the neural pathways. The transfer of energy with minimal dissipation would explain why a semiconductor like property is needed and why acupuncture points have a high conductivity value.

4. What about acu-points? Acu points are known to be in negative potential normally. This suggests that the density of electrons or their Cooper pairs at them is higher than elsewhere in the meridian. Could they server as kind of electron stores providing electrons to their environment to compensate for losses caused by ROS. This would make possible higher metabolic activity in presence of nutrient molecules since the rate for the electron transform cycle should be proportional to the density of energizable electrons, "chi".

   When the potential of the acu-point is reduced or become positive, under-nutrition follows. This should relate to various symptoms like pain at acupuncture points. Acupuncture needle as an electronic conductor would develop a charge distribution with a concentration of electrons to the acu-point, and would re-establish the metabolic activity. Pain would be signature of lack of negentropic entanglement (see **Fig.** `http://tgdtheory.fi/appfigures/cat.jpg` or **Fig. ??** in the appendix of this book) and positive/negative coloring of emotions and sensations would quite generally correlate with the amount of negentropic entanglement.

5. Nanna Goldman *et al* have provided empirical evidence (see `http://tinyurl.com/4to42pc`) [I49] for the expectation that the healing effect of the acupuncture involves metabolism (see the popular article in Sciencedaily (see `http://tinyurl.com/3734uub`) [I24]).

   The group has found that adenosine is essential for the pain killing effects of acupuncture. For mice with a normal adenosine level acupuncture reduced dis-comfort by two-thirds. In special "adenosine receptor knock-out mice" acupuncture had no effect. When adenosine was turned on in the tissues, the discomfort was reduced even in the absence of acupuncture. During and after an acupuncture treatment, the level of adenosin in tissues near the needles was 24 times higher than before the treatment. In the abstract of the article it is stated that it is known for long time that acupuncture generates signals which induce brain to generate natural pain killing endorphins but that also adenosine acts as a natural pain killer.

   Adenosine is the basic building block of AXP, X=M, D, T (adenosin-X-phosphate, X=mono, di, tri). Therefore the findings suggest that the flow of electrons from the needle to acu point loads metabolic batteries by providing electrons to electron transport cycle needed to generate ATP. Adenosine could be partially generated as decay products of AXPs. Tissue itself could increase adenosine concentration to make possible its transformation to AXP utilizing electric field energy. From the popular article one cannot conclude whether the authors propose a connection with metabolism. The results are consistent with the assumption that the AXPs generated from adenosin accompany negentropic entanglement. This can occur in the scale of entire body and meridians could also make possible direct signalling with brain.

How can understand the semiconducting character of Becker's DC currents?

1. Becker assigns to the system involved with DC currents an effective semiconductor property. Could the effective semiconductor property be due the fact that the transfer of charge carriers to a smaller space-time sheet by first accelerating them in electric field is analogous to the transfer of electrons between conduction bands in semiconductor junction? If so, semiconductor property would be a direct signature of the realization of the metabolic energy quanta as zero point kinetic energies. For metabolic energy quantum of order .5 eV this however makes sense only if the electrons transferred to the smaller space-time sheet have energy slightly below the minimum energy for the transfer to the smaller space-time sheet in absence of the Becker potential. The situation would be critical and 1 mV voltage could serve as a kind of control knob.

   One can imagine the analog of this mechanism also when the external energy feed corresponds to a phase transition reducing p-adic length scale and increasing Planck constant so that the size of the space-time sheet remains unaffected. Again 1 mV voltage would have the role of control knob.

2. Supra currents flowing along magnetic flux tubes would make possible dissipation-free loading of metabolic energy batteries. This even when oscillating Josephson currents are in question since the transformation to ohmic currents in semiconductor junction makes possible energy transfer only during second half of oscillation period. Could this be a universal mechanism applying to various stages of the regeneration process? In quantal situation the metabolic energy quanta have very precise values as indeed required.

3. The findings of Becker provide support for electronic DC currents. The Cooper pairs of electrons are indeed the best candidates for the carriers of supra current by their small mass. In the minimal situation the currents defined by leaked electrons moving against potential gradient (utilising the energy used otherwise to generate ATP) could compensate the Becker currents and give rise to closed current loops without charge accumulation. If the electronic DC currents observed by Becker are much stronger than needed to compensate for the local electron leakage, a larger metabolically driven return current is needed to guarantee local charge neutrality. These currents seem to be assignable to CNS: maybe the two electron currents could be associated with sensory and motor pathways. An interesting question whether sympathetic-parasympathetic dichotomy also relates to electron currents in opposite directions.

4. Could also dark protonic and even ionic DC currents be present and running along their own flux tubes and perhaps defining cyclotron Bose-Einstein condensates? How large the scale of flux tubes can be: could it be much larger than that of biological body (by simple argument magnetic body should have layers with even size scale of Earth). What is the possible connection with cell respiration? When single ATP is generated, three protons are are pumped through the mitochondrial membrane utilising the energy liberated in electron transport cycle. This does not however require protonic currents in longer scales.

5. In regeneration process NEJs are formed. They could consist of pairs of MEs and magnetic flux tube mediating the electronic DC current during blastema generation and regeneration proper during which also control signals from CNS would be present. Since NEJs seems to resemble cell membranes in some respects, the ideas inspired by the model of cell membrane and DNA as TQC can be used. The model for nerve pulse and the model for DNA as topological quantum computer suggest that dark ionic currents flowing along magnetic flux tubes characterised by a large value of the effective Planck constant are involved with both meridians and NEJs. Magnetic flux tubes can act as DC current wires or Josephson junctions generating oscillatory supra currents of ions and electrons. Also for large values of the effective Planck constant meridians look short in the relevant dark length scale and could act as Josephson junctions carrying oscillatory Josephson currents.

One can raise also questions about the relationship between DC currents and de-differentiation.

1. Could cell de-differentiation be caused by the presence of Becker's DC current? Also acupuncture is known to induce de-differentiation. Could the mere ability to charge metabolic energy batteries provided by electron feed induce de-differentiation, which manifests as an increased genetic expression? Can one see differentiation as an eliminative process forced by the reduction of the electron feed and inducing a selective reduction of gene expression? If this were the case, de-differentiation could be induced by a feed of surplus electrons to the system using either external electron current or additional electric field. Local electron density would correlate negatively with the degree of differentiation.

2. In this framework it might be possible to understand the claimed effects of external electric fields on the development of plants and fishes. In this case rejuvenation means return to the earlier evolutionary stages. Maybe ontogeny-recapitulates-phylogeny principle might allow to understand this if genome in some sense contains archive about earlier stages of evolution. This archive might be virtual and realised by an epigenetic mechanism selecting different patterns of gene expression using the same genome.

   If this is the case, the density of electrons or their Cooper pairs - "chi" - possessed by the cell would serve as a measure for the biological age of the cell and the meridian system feeding "chi" would serve as a rejuvenating agent with respect to gene expression. The average density of dark electrons would serve as a measure for the age of cell: the larger the density the higher the metabolic activity and the lower the biological age.

3.7.2 Quantum Model For Effective Semiconductor Property

Becker [J15] summarizes his findings by stating that living matter is an effective semiconductor. There are pairs of structures in positive and negative potential in various scales and the current between the plates of this effective capacitor flows when above some minimum potential difference. The current flows from positive to negative pole and could be an electron current. Also proton current in the opposite direction can be considered but the electron current is experimentally favored. For instance consciousness is lost when a magnetic field is used to deflect the current.

In TGD framework natural carriers of these currents would be magnetic flux tubes also carrying electric fields. A very simple deformation of the embedding of a constant longitudinal magnetic field also gives longitudinal electric field. With a slight generalization one obtains helical electric and magnetic fields. A crucial difference is that these currents would be quantal rather than ohmic currents even in the length scale of the biological body and even longer scales assignable to the magnetic body.

The following argument allows us to understand the physical situation.

1. A precise everyday analogy is vertical motion in the gravitational field of the Earth between surface and some target at given height h. If the kinetic energy is high enough, the particle reaches the target. If not, the particle falls back. In the quantum case one expects that the latter situation corresponds to a very small probability amplitude at the target (tunnelling to classically forbidden kinematic region).

2. Now the electric field replaces the gravitational field. Suppose that the classical electric force experienced by the particle is towards the capacitor plate taking the role of the surface of Earth. Below critical field strength the charged particle cannot reach the target classically and quantum mechanically this occurs only by tunnelling with vanishingly small probability.

3. Particles with opposite value of charge experience a force which accelerates them and classically they certainly reach the second plate. What happens in a quantum situation? It seems that this situation is essentially identical with the first one: one has linear potential in finite interval and wave functions are localized in this range. One can equivalently regard these states as localized near the second capacitor plate.

4. A good analogy is provided by atoms: classically the electron would end down at the nucleus but quantization prevents this. One can imagine also now stationary solutions for which the electric currents for individual charges vanish at the plates although classically there would be a current in another direction. Also quantum mechanically non-vanishing conserved current is possible: all depends on boundary conditions.

Basic model

Consider now the situation at more quantitative level.

1. One can assign complex order parameters Ψ_k to various Bose-Einstein condensates of supra phases and obey Schrödinger equation

$$i\partial_t\Psi_k = (-\frac{\hbar^2}{2m_k}\partial_z^2 + q_kEz)\Psi_k \ . \tag{3.7.1}$$

Here it is assumed that the situation is effectively one-dimensional. E is the value of constant electric field.

2. The Schrödinger equation becomes non-linear, when one expresses the electric field in terms of the total surface charge density associated with the plates of effective capacitor. In absence of external electric field it is natural to assume that the net surface charge densities σ at the plates are of opposite sign so that the electric field inside the capacitor is proportional to

$$\sigma = E = \sum \sigma_i = \sum_i q_i \overline{\Psi}_i \Psi_i \ . \tag{3.7.2}$$

This gives rise to a non-linear term completely analogous to that in non-linear Schrödinger equation. A more general situation corresponds to a situation in which the region interval $[a, b]$ bounded by capacitor plates a and b belongs to a flux longer tube like structure $[A, B]$: $[a, b] \subset [A, B]$. In this case one has

$$E_{tot} = E + E_0 \ . \tag{3.7.3}$$

This option is needed to explain the observations of Becker that the local strengthening of electric field increases the electron current: this would be the case in the model to be discussed if this field has a direct opposite to the background field E_0. One could also interpret E as quantized part of the electric field and E_0 as classical contribution.

3. The electric currents are given by

$$j_k = \frac{i\hbar q_k}{2m_k} \overline{\Psi}_k \partial_z^{\leftrightarrow} \Psi_k \ . \tag{3.7.4}$$

In stationary situation the net current must vanish:

$$\sum_k j_k = 0 \ . \tag{3.7.5}$$

A stronger condition is that individual currents vanish at the plates:

$$j_k = 0 \ . \tag{3.7.6}$$

It must be emphasized that this condition does not make sense classically.

Explicit form of Schrödinger equation

Consider now the explicit form of Schrödinger equation in a given electric field.

1. The equation is easy to solve by writing the solution ansatz in polar form (the index k labelling the charge particle species will be dropped for notational convenience).

$$\Psi = R(aexp(iU) + bexp(-iU))exp(-iE_n t) \tag{3.7.7}$$

For real solutions current vanishes identically and this is something which is not possible classically. It is convenient to restrict the consideration to stationary solutions, which are energy eigen states with energy value E_n and express the general solution in terms of these.

2. The Schrödinger equation reduces with the change of variable

$$\begin{aligned} z &\rightarrow \frac{(z-z_0)}{z_1} \equiv x \ , \\ z_0 &= \frac{E_n}{qE} \ , \ z_1 = (\frac{\hbar^2}{2mqE})^{1/3} \ . \end{aligned} \quad (3.7.8)$$

to

$$(\partial_x^2 + x)\Psi = 0 \ . \quad (3.7.9)$$

The range $[0, z_0]$ for z is mapped to the range $[-z_0/z_1, 0]$. z_0/z_1 has positive sign as is easy to verify. The value range of x is therefore negative irrespective of the sign of qE. This is the differential equation for Airy functions (see `http://tinyurl.com/6b8yh7`) [B1]. Airy functions are encountered in WKB approximation obtained by linearing the potential function: $V(x) = ax + b + O(x^2)$.

The change of variable leads automatically to solutions restricted near the plate where the situation is completely analogous to that in the gravitational field of the Earth. For stationary solutions a test charge in a given background field would be localized near the capacitor plate with opposite sign of charge. A strong background field could be created by charges which do not correspond to the ionic charges defining ionic currents. Electrons and protons could define this field possibly associated with flux tubes considerably longer than the distance between capacitor plates.

3. Using the polar representation $\Psi = Rexp(iU)$ Schrödinger equation reduces to two equations

$$\begin{aligned} \left[(\partial_x^2 - U_x^2 + x)R\right] cos(U) &+ [U_{xx} + 2\partial_x R \partial_x U] \, sin(U) = 0 \ , \\ \left[(\partial_x^2 - U_x^2 + x)R\right] sin(U) &- [U_{xx} - 2\partial_x R \partial_x U] \, cos(U) = 0 \ . \end{aligned} \quad (3.7.10)$$

Note that both (R, U) and $(R, -U)$ represent solutions for given value of energy so that the solution can be chosen to be proportional to $cos(U)$ or $sin(U)$. The electric current j is conserved and equal to the current at $x = 0$ and given by

$$j = \frac{\hbar}{2m}\frac{U_x}{z_1}R^2 \ , \ z_1 = (\frac{\hbar}{2mqE})^{1/3} \ . \quad (3.7.11)$$

The current vanishes if either U_z is zero or if the solution is of form $\Psi = Rsin(U)$.

Semiclassical treatment

In semiclassical approximation the potential is regarded as varying so slowly that it can be regarded as a constant. In this situation one can write the solution of form $Rexp(iU)$ as

$$\Psi = R_0 exp\left(\frac{i}{\hbar}\int_0^z \sqrt{2m}\sqrt{E - qEz}dz\right) = R_0 exp\left(i\int_0^x x^{1/2}dx\right) \ . \quad (3.7.12)$$

The plate at which the initial values are given can be chosen so that the electric force is analogous to gravitation at the surface of Earth. This requires only to replace the coordinate z with a new one, vanishing at the plate in question - and gives to the energies a positive shift $E_0 = qE_0h$.

1. The semiclassical treatment of the equation leads to Bohr rules

$$\frac{\oint p_z dz}{\hbar} = \frac{2}{\hbar}\int_0^h p_z dz = n \ . \tag{3.7.13}$$

This gives

$$\frac{\oint p_z dz}{\hbar} = \frac{2\sqrt{2m}}{\hbar}\int_0^h \sqrt{E_n - qEz}dz = 2\int_0^{x_0} x^{1/2} = \frac{4}{3}x_0^{3/2} = n \ . \tag{3.7.14}$$

Note that the turning point for classical orbit corresponds to $z_{max} = E_n/qE$.

2. One obtains

$$E_n = \frac{1}{2}(\frac{nqE\hbar^2}{r\sqrt{m}})^{2/3} \ , \ r = \int_0^1 (1-u)^{1/2}du = \frac{2}{3} \ . \tag{3.7.15}$$

The value of z_{max} is

$$z_{max} = \frac{E_n}{qE} = \frac{n^{2/3}}{2r^{2/3}}(\frac{\hbar^2}{qEm})^{1/3} \ . \tag{3.7.16}$$

3. The approximation $R = R_0 = constant$ can make sense only if the position of the second plate is below z_{max}. This is possible if the value of n is large enough ($n^{2/3}$ proportionality), if the mass m of the charged particle is small enough ($m^{-1/3}$ proportionality) raising the electron and also the proton to a special position, or if the strength of the electric field is small enough ($E^{-1/3}$ proportionality). The value z_{max} is proportional to $\hbar^{2/3}$ so that a phase transition increasing Planck constant can induce current flow.

Possible quantum biological applications

The proposed model for quantum currents could provide quantum explanation for the effective semiconductor property of Becker's DC currents.

1. The original situation would be stationary with no currents flowing. The application of an external electric field in the correct direction would reduce the voltage below the critical value and currents would start to flow. This is consistent with Becker's findings if there is a background electric field E_0 with direction opposite to that of the applied field has a direction opposite to E_0 so that the field strength experienced by charged particles is reduced and it is easier for them to reach the second plate.

2. Becker's DC currents appear in several scales. They are assigned with the pairs formed by CNS and perineural tissue (this includes also glia cells) and by frontal and occipital lobes. Acupuncture could involve the generation of a DC supra current. The mechanism would be essential in the healing. Also the mechanism generating qualia could involve generation of supra currents and dielectric breakdown for them. The role of the magnetic flux tubes in TGD inspired biology suggests that the mechanism could be universal. If this were the case one might even speak about a Golden Road to the understanding of living matter at the basic level.

Even the generation of nerve pulse [K82] might be understood in terms of this mechanism. One can argue that neurons have a higher evolutionary level than the system pairs to which only electron currents or electron and proton currents can be assigned. This is because the value of the effective Planck constant is higher for the magnetic flux tubes carrying the quantal ionic currents.

1. For Bose-Einstein condensate the simplest choice is $n = 1$ at both plates. The energy eigenvalues would naturally differ by the shift $E_0 = qE_0h$ at the two plates for a given particle type. Under these assumptions the current can flow appreciably only if the voltage is below the minimum value. This is certainly a surprising conclusion but brings in mind what happens in the case of neuronal membrane. Indeed, hyper-polarization has a stabilizing - something difficult to understand classically but natural quantum mechanically.

2. The reduction of membrane potential slightly below the resting potential generates nerve pulse. Also a phase transition increasing the value of the effective Planck constant might give rise to quantal direct currents and generate flow of ionic currents giving rise to nerve pulse. Stationary solutions are located near either capacitor plate. What comes to mind is that the nerve pulse involves a temporary change of the capacitor plate with this property.

3. If the electron and proton currents flow as direct currents, one encounters a problem. Nerve pulse should begin with direct electronic currents and be followed by direct protonic currents and only later ions should enter the game if at all. The existing model for nerve pulse however assumes that at least electrons flow as oscillating Josephson currents rather than direct quantal currents. This is quite possible and makes sense if the cell membrane thickness is small - that is comparable to electron Compton length as assumed in large $\hbar$ model for the nerve pulse. This assumption might be necessary also for proton and would make sense if the Planck constant for protonic flux tubes is large enough. For ions the Compton length would be much smaller than the thickness of cell membrane and direct currents would be natural.

   If the value of the effective Planck constant is the same for biologically important ions, direct quantum currents would be generated in definite order since in $h < z_{max}$ one has $z_{max} \propto m^{-1/3} \propto A^{-1/3}$. The lightest ions would start to flow first.

   (a) Nerve pulses canbe generated by voltage gated channels for potassium and calcium. Voltage gated channels would correspond to magnetic flux tubes carrying electric field. For voltage gated channels Na$^+$ ions with atomic weight $A = 23$ and nuclear charge $Z = 11$ start to flow first, then K^+ ions with atomic weight $A = 39$ and $Z = 19$ follow. This conforms with the prediction that the lightest ions flow first. The nerve pulse duration is of the order of 1 millisecond at the most.

   (b) Nerve pulses can be also generated by voltage gated Ca^{+2} channels. In this case the duration can be 100 ms and even longer. Ca has $A = 40$ and $Z = 20$. The proper parameter is $x = r^2/qA$, $r = \hbar/\hbar_0$. One has

   $$\frac{x(Ca^{++})}{x(Na^+)} = (\frac{r(Ca^{++})}{r(Na^+)})^2 \times \frac{23}{2 \times 40} \quad . \tag{3.7.17}$$

   $r^2(Ca_{++}) \sim 2r^2(Na_+)$ would allow to compensate for the increased weight and charge of Ca_{++} ions.

4. The objection is that Na^+ and K^+ are not bosons and therefore cannot form Bose-Einstein condensates. The first possibility is that one has Cooper pairs of these ions. This would imply

   $$\frac{x(Ca^{++})}{x(2Na^+)} = (\frac{r(Ca^{++})}{r(Na^+)})^2 \times \frac{23}{20} \quad .$$

   Ca^{++} and Na^+ pair would be in very similar position for a given value of Planck constant. This is a highly satisfactory prediction. Another manner to circumvent the problem is more science fictive and assumes that the Na^+ ions are exotic nuclei behaving chemically as Na^+ but having one charged color bond between nucleons [L3].

It remains to be seen whether this model is consistent with the model of cell membrane as almost vacuum extremal or whether the vacuum extremal based model could be modified by treating ionic currents as direct currents. In the vacuum extremal model classical Z^0 gauge potential is present and would give a contribution to the counterpart of Schrödinger equation. The ratio $x(Ca^{++})/x(2Na^+)$ for the parameter $x = r^2/q(A-Z)A$ (em charge q is replaced with neutron number in good approximation) equals to 1.38 and is not therefore very far from unity.

The many-sheetedness of space-time is expected to play a key role and one should precisely specify which sheets are almost vacuum extremals and which sheets are far from vacuum extremals. One expects that magnetic flux tubes are far from vacuum extremals and if voltage gated ionic channels are magnetic flux tubes, the proposed model might be consistent with the model of cell membrane as almost vacuum extremal.

The effects of ELF em fields on vertebrate brain

The effects of ELF em fields on vertebrate brain occur both in frequency and amplitude windows. Frequency windows can be understood if the effect occur at cyclotron frequencies and correspond to absorption of large $\hbar$ photons. A finite variation width for the strength of magnetic field gives rise to a frequency window. The observed quantal character of these effects occurring at harmonics of fundamental frequencies leads to the idea about cyclotron Bose-Einstein condensates as macroscopic quantum phases. The above considerations support the assumption that fermionic ions form Cooper pairs.

I have tried to understand also the amplitude windows but with no convincing results. The above model for the quantum currents however suggests a new approach to the problem. Since ELF em fields are in question they can be practically constant in the time scale of the dynamics involved. Suppose that the massless extremal representing ELF em field is orthogonal to the flux tube so that the ions flowing along flux tube experience an electric force parallel to flux tube. What would happen that the ions at the flux tube would topologically condensed at both the flux tube and massless extremal simultaneously and experience the sum of two forces.

This situation is very much analogous to that defined by magnetic flux tube with longitudinal electric field and also now quantum currents could set on. Suppose that semiconductor property means that ions must gain large enough energy in the electric field so that they can leak to a smaller space-time sheet and gain one metabolic quantum characterized by the p-adic length scale in question. If the electric field is above the critical value, the quantum current does not however reach the second capacitor plate as already found: classically this is of course very weird. If the electric field is too weak, the energy gain is too small to allow the transfer of ions to smaller space-time sheet and no effect takes place. Hence one would have an amplitude window.

The amplitude window occur in widely separate ranges 1-10 V/m and around 10^{-7} V/m. Of course, also other ranges might be possible. Fractality and the notion of magnetic body suggests a possible explanation for the widely different frequency ranges. Both p-adic length scale hypothesis and the hierarchy of Planck constants suggest that some basic structures associated with the cell membrane have fractal counterparts in a wide length scale range and correspond to binary structures. Magnetic flux tubes carrying quantal DC currents of Becker would be the most natural candidate in this respect since these currents appear in several length scales inside organism. Also the counterparts of lipid layers of cell membrane could be involved. If so, one must include to the hierarchy of amplitude windows also fields in the range corresponding to the cell membrane resting potential of about 6×10^6 V/m. This is of course only a rough order of magnitude estimate since perturbations of these field are in order.

Fractality motivates some guess for voltage and electric field.

1. The voltage along the flux tube could be invariant under the scaling of Planck constant. The interpretation could be that the charges at the ends of the linear structure generate an electric flux running along the structure do not depend on the length L of the structure so that the electric field along linear structure behaves as $1/L \propto 1/h_{eff}$ as a function of the length scale $L \propto h_{eff}$ so that voltage between the ends does not depend on the length of the structure. This would give rise to a universal amplitude window for voltage rather than potential. The cell membrane electric field of 6×10^6 V/m would correspond to the field 6 mV/m. This kind of voltages could be associated with Becker's DC currents and the order of magnitude would be around few mV.

Note that if the electric flux is like that between point charges, the scaling law $E \propto 1/h_{eff}^2$ holds true.

2. There could be also a constant electric field along microtubular structures due to polarization - most naturally tubulin polarization. This field strength serves as a candidate for a universal amplitude window for electric field.

   The idea that the direct currents of Becker run between lipid layers of cell does not conform with the hypothesis about generalized Josephson currents between them. There are electric fields along microtubules and one could wonder whether the DC voltages of Becker could relate to the voltages between the ends of linear structures formed by axonal and dendritic microtubules connected to each other by MAPs - single MT can have a length up to about 1 cm. The longitudinal electric field due to the dipole moments of tubulins and confined to tubulin structure does not depend on its length L, and the electric field of 1 mV/m would correspond 10^3 V/μm, which is by order of magnitude larger than the constant longitudinal dipole electric field of order 10^2 eV/μm generated by tubulin dipoles estimated to have strength 337 Debye in [I57] (note that MT has radius of $R = 25$ nm, thickness of $\Delta R = 4$ nm and length of $d = 8$ nm and the volume of MT fragment defined by 13 parallel tubulins is given by $V = 13 \times 2\pi R^2 \Delta R$ and that electric is $E = p/V$). If Becker's direct currents correspond to electric fields due to the charge difference between the ends of tubulins, one can consider the possibility that Becker's longitudinal electric fields have micro.tubular origin.

3. Electric field in the range $E = 1 - 10$ V/m assignable to EEG would correspond to field of $(1 - 10) \times 10^3$ V/μm and seems to be too large to be assigned with microscopic structures. DNA is a possible candidate since the smaller thickness of DNA would increase the dipole moment density by a factor of order 10^3 from that for MTs. The electric field of 10^{-7} eV/m seems to be associated with much larger structure than organism.

Effects of 50 Hz magnetic fields on living matter

The vision about the role of cyclotron Bose-Einstein condensates was inspired by the effects of ELF em fields on vertebrate brain. The magnetic field strength explaining the effects was about.2 Tesla, 2/5 of the nominal value for the strength of Earth's magnetic field.

There are also other experiments have demonstrated that oscillating electromagnetic fields have effects on living matter. In particle oscillatory magnetic fields with frequency of 50 Hz and with field strengths typically in the range.1-1 mT are used: these effects are summartized in [J75]. Even fields of order.14 Tesla are used.

It is interesting to look at the values of basic parameters associated with these fields.

1. For 50 Hz oscillation frequency the wave length λ is 6000 km to be compared with the radius of Earth which is 6371 km. If one takes seriously the notion of magnetic body this need not be an accident. I do not know how essential it is to have just 50 Hz frequency. The magnetic field is nearby oscillating dipole field (see `http://tinyurl.com/36c4pfg`) up to distances of order λ and radiation field at much longer distances. Therefore the field in question is in good approximation nearby field as fart as biological body is considered. For magnetic body the radiation field could dominate

2. For the endogenous magnetic field $B_{end} = .2$ Gauss cyclotron frequencies of ions are in EEG range: Ca^{++} cyclotron frequency is 15 Hz. The scaling up to r=.1-1 mT means scaling of cyclotron frequencies by a factor $5 - 50$. For Ca^{++} this would give frequency range 75-750 Hz. For K^+ and Cl^+ ions the frequency range would be about 35-375 Hz.

3. The magnetic length $r = \sqrt{2/eB}$ characterizing flux tube thickness for flux quantization with minimum value of flux is for $B = .05$ mTesla equal to 5 μm. For the fields in the range .1-1 mTesla it is in the range 3.5 μm- 1.1 μm. 2.5 μm corresponds to p-adic length scales $L_e(k)$ associated with Gaussian Mersenne $M_{G,k} = (1+i)^k - 1$, $k = 167$, and Gaussian Mersenne correspondng to $k = 163$ would correspond to p-adic length scale .36 μm. .14 Tesla corresponds to magnetic length of 9.4 nm rather near to cell membrane thickness of 10 nm which corresponds to p-adic length cale $L_e(151)$ assignable to Gaussian Mersenne $M_{G,151}$.

The effects of polarized light on living matter

Polarized light is known to have effects on living matter [J75]. For instance, Peter Gariaev has found that the polarized light generated by living matter sample irradiated by polarized laser light has effects on distant organism and there are even indications that genetic code might be realized in terms of radiation patterns [K123]. The quantum model for Becker currents suggest that these effects result as a modification of the voltage between the ends of magnetic flux tubes If the flux tubes are near criticality for the generation of quantal DC currents, polarized light could be utilized both communication and control purposes wheres the acceleration in the electric fields along flux tubes would serve as a provider of metabolic energy allowing to load metabolic batteries. This process could be initiated by an electromagnetic signal inducing generation of quantal currents. The same basic mechanism could be at work also in DNA transcription, replication and other similar processes.

If the polarized low frequency radiation corresponds to a massless extremal (ME) orthogonal to the flux tube such that the polarization of the radiation is parallel to the flux tube, the voltage is affected by a contribution given by $\Delta V = Ed$, d the thickness of ME. If the flux tube is near criticality to a generation of quantal currents this change of voltage could serve as a signal inducing the generation of quantal currents.

The maximal effect is obtained for the flux tubes having direction parallel to the electric polarization so that the effect is highly selective. In the case of DNA double strand the direction of flux tube changes so that the effect would be maximal on DNAs which correspond to the same angular position on the super-coil of radius of order 10 nm formed by DNA double helix. This allows to imagine signals for which temporal variation of polarization direction means scanning of DNA.

It is known that the energy of radiation can be transformed to metabolic energy. For instance, IR light for which photons have energies of order metabolic quantum has biological effects [I105]. The mechanism could be following. Suppose that the electric field of IR photon is parallel to the flux tube which carries an electric field and is near criticality for the generation of quantal DC currents. If the direction of polarization is correct, the additional contribution to electric field induces direct current and acceleration of electrons and protons and their transfer to smaller space-time sheets and therefore loading of metabolic batteries. This could also make generation of ATP possible.

Suppose that one takes seriously the model for remote replication of DNA [K123] involving flux tubes connecting identical DNA nucleotides and that the radiation propagating along them induces quantal currents along the receiving DNA inducing replication and perhaps even transcription. The direction of polarization for the emitted radiation should be parallel to the DNA strand locally and during its travel to the target the polarization should remain orthogonal to the flux tube so that one would have what might be called polarization window. Parallel translation of the polarization vector in the induced metric suggests itself.

Support for the proposed interaction mechanism of em radiation fields with flux tubes

The basic prediction of the interaction mechanism is that the effects of em field with a given frequency occur only at the second half period when the direction of electric field is "correct". This prediction might be testable. In fact, there is evidence for this interaction mechanism in the case of theta waves of EEG. The memory storage occurs only at the second half of the theta wave This is discussed from different point of view in [K5].

The place coding by phase shifts was discovered by O′Reefe and Recce [J63]. In [J80, J79]. Y. Yamaguchi describes the vision in which memory formation by so called theta phase coding is essential for the emergence of intelligence. It is known that hippocampal pyramidal cells have "place property" being activated at specific "place field" position defined by an environment consisting of recognizable objects serving as landmarks. The temporal change of the percept is accompanied by a sequence of place unit activities. The theta cells exhibit change in firing phase distributions relative to the theta rhythm and the relative phase with respect to theta phase gradually increases as the rat traverses the place field. In a cell population the temporal sequence is transformed into a phase shift sequence of firing spikes of individual cells within each theta cycle.

Thus a temporal sequence of percepts is transformed into a phase shift sequence of individual spikes of neurons within each theta cycle along linear array of neurons effectively representing time axis. Essentially a time compressed representation of the original events is created bringing in mind temporal hologram. Each event (object or activity in perceptive field) is represented by a firing of one particular neuron at time τ_n measured from the beginning of the theta cycle. τ_n is obtained by scaling down the real time value t_n of the event. Note that there is some upper bound for the total duration of memory if scaling factor is constant.

One can say that neurons in ensemble provide a representation for the external world and the location of the rodent in the external world is represented as a firing of a neuron in this landscape. Besides this also temporal scaling down by a factor about ten is carried out so that actual event is represented as much shorter copies of it. Obviously this represents temporal fractality.

This scaling down - story telling - seems to be a fundamental aspect of memory. Our memories can even abstract the entire life history to a handful of important events represented as a story lasting only few seconds. This scaling down is thought to be important not only for the representation of the contextual information but also for the memory storage in the hippocampus. Hierarchy of Planck constants and phase transitions changing Planck constant make this story building possible.

The finding of Yamaguchi and collaborators relevant in the recent context is that the gradual phase shift occurs at half theta cycle whereas firings at the other half cycle show no correlation [J80]. The proposed model for the interaction of theta waves with flux tubes could explain this naturally. The relevant neural sub-system would be critical to the generation of quantal DC current only when the direction electric field of synchronizing theta wave generated by magnetic body is correct. Hence synchronous neural activity would be induced only at second half cycle of theta wave and firing would be random during the other half cycle.

3.7.3 A Model For Remote Gene Expression Based On Becker Currents

If one accepts the notion of magnetic body as intentional agent, the basic challenge is to understand how magnetic body realizes its intents as remote mental interactions on biological body. This model must of course apply also to the more conventional remote mental interactions such as remote realization of intent.

The hypothesis is that electromagnetic and possibly also other massless classical fields assignable to so called massless extremals are in a key role. Also cyclotron frequencies characterizing magnetic bodies play a key role. The vision is that magnetic flux sheets traverse many-sheeted DNA in various scales giving rise to a hierarchy of genomes and coherent gene expression in scales of cell, organelles, organism, and even population, and species. Hierarchy of Planck constants is in an essential role in realizing this hierarchy in terms of photons with energies above the thermal energy at physiological temperature and having spectrum of wavelengths coming as multiples $\lambda = n\lambda_0$, $n = \hbar/\hbar_0$.

The findings of Benveniste and followers relating to water memory and homeopathy, the recent work of group led by HIV Nobelist Luc Montagnier coupling the findings with genetics and suggesting a new nanoscale realization of genetic code [L4]), the work of the group of Popp with bio-photons identified as decay produces of large $\hbar$ photons with visible energies (in particular dark EEG photons), and the work of Peter Gariaev and collaborators supporting remote gene expression and replication discussed [K123] suggest that electromagnetic radiation is indeed involved. In the case of water memory and homeopathy the spectrum of cyclotron frequencies for the chemical invader characterizes it and induces immune response trying to eliminate it. I have also proposed a model for how genes coding for proteins eliminating the invader could be generated almost automatically: the model is based on the predicted realization of vertebrate genetic code in terms of dark proton states [K44]. DNA would like an animal which sniffs the invaders magnetic body and automatically reacts to the smell.

The discussions with Lian Sidorov and people who have realized that new era is beginning in biology have served as a driving force in the attempts to formulate in more detail TGD inspired view about how remote mental interactions - which are basic element of the model in TGD framework - might be realized. As a matter fact, I have added to my homepage a new book summarizing briefly the recent view about quantum TGD and its applications to quantum consciousness, quantum biology, to quantum neuroscience, and to remote mental interactions with some proposals for possible tests [K104]).

To start with, suppose that in the case of biological target realization of intent in the simplest situation reduces to expression of genes. This is of course a strong limitation to the type of remote mental interactions. The challenge is to develop a model for remote realization of genetic activities like replication, and transcription. For some time ago I proposed a model with Peter Gariaev [K123] but it was still too clumsy since it required too much of information transfer between the genomes of sender and receiver. Much simpler model involving only sending of simple commands initiating genetic programs suggests itself. The following proposal tries to achieve this and involves three basic ideas.

1. The idea of password and addressing is familiar from ordinary computers. Collection of frequencies as password/address allows to reach tuned targets without specific targeting of the command. This is a dramatic improvement to the previous model.

2. Password and fractal addressing realized in terms of frequencies coupling resonantly (already in the original model: I did not however realize the implications of resonant coupling!) and the hierarchy of Planck constants to realize the hierarchical addressing. I have discussed analogous addressing based on information molecules and their receptors at the biochemical level to realize magnetic flux tube connections between sender and target inside organism (hormonal action would be very analogous to what I am proposing here).

3. Becker's DC currents as supra currents flowing along DNA and activated optimally when the incoming laser light has polarization parallel to DNA's local direction, activation of super currents would mean activation of the gene. This is second new element to the original model.

In the following I discuss this with more details.

The analogy with ordinary computer

Consider first the analog of remote mental interactions for ordinary computer. Computer sends a password to the other computer and after that it can use it to run programs of the other computer. Whisling to a dog is another example: extremely simple command activates arbitrary complex programs.

In the recent case electromagnetic radiation with a given frequency coupling resonantly like radio signal to a tuned radio receiver would be the simplest command activating the target. There would no need to specify the direction or distance of the target precisely since essentially mass communications would be in question: intent would be enough. Password could consist of several frequencies which must be received simultaneously by the target before it would activate and tunes to receive more frequencies representing simple commands - perhaps acting on the intronic portion of DNA and activating the genome to remote gene expression or something else such as activating DNAs of other cells by sending similar em addresses!

I have discussed topological quantum computer programs (see `http://tinyurl.com/y84g3tk7`) based on braiding could look like in this framework [L9]. Also here addressing but now realized as information molecule-receptor pair would play a key role.

Hierarchy of Planck constants and hierarchical addressing

Fractal hierarchy of frequencies (in Peter's experiment laser light induced generation of radiation at frequencies down to about 10 kHz) would allow to transform passwording to addressing. Very naïvely, the longest wavelengths: about 10^4 meters would reach the tuned receivers in nearly the same phase in a region of this size. One would have some subregions in tune. The shorter wavelengths would allow to pinpoint the tuned receivers inside each of these subregions and so on. This would be fractal addressing with most significant bits correspond to the longest wavelengths. Only those receivers which would be tuned to all frequencies would start to express the gene in the case of AND logic. Of course, also other Boolean functions of tuned-not tuned bits can be considered.

A good guess is that all photons correspond to the same energy of visible photon and only Planck constant varies. For ordinary value of Planck constant one would have a photon with wavelength of order size scale of single cell, and the frequencies in this range would select single gene in the genome ofa particular kind of cell, say neuron within particular region of brain.

In Peter Gariaev's experiment involving 2 eV incoming red laser light the outgoing photons would have same energy but larger Planck constant so that also wavelengths would be longer and range down to at least 3×10^4 meters corresponding to radiofrequency scale of 10 kHz. What is interesting that 2 eV is 4 times the nominal value of the metabolic energy quantum of.5 eV identifiable as zero point kinetic energy of electron or proton for the p-adic length scale $L_e(151)$ corresponding to cell membrane thickness and Gaussian Mersenne $M_{151} = (1+i)^{151} - 1$. Could it be that 2 eV could be preferred photon energy or is its use simply due to the unavailability of continuous frequency spectrum for laser light. And why the laser light induces the generation of the command inducing remote gene expression?

This picture conforms with Peter's experiment and with the reports of Benveniste and followers about the possibility of representing homeopathic remedy using very low frequency spectrum - presumably cyclotron frequencies - assignable to remedy. These frequencies would be addresses for genes activating genes transcribing building bricks of biomolecules of immune response eliminating the substance from the organism. The proposal could be seen as a generalization of Benveniste's observation and realization of wave DNA proposal.

DNA supra currents and activation of genes by Becker mechanism

The third bulding brick of the model would be quantum model for Becker currents (see `http://tinyurl.com/ybnjk9bq`) [L10] as supra currents or quantal DC currents: also this element is new. Assume - in accordance with the general vision - that these supra currents can flow also along the strands of many-sheeted DNA (flux sheets associated with the strand, entire hierarchy labelled by the values of $\hbar$). Assume also that the interaction of polarized photons addressing for genes with DNA is such that the electric fields of DNA flux tube and "massless extremal" representing laser beam superpose and charges (electrons) experience the superposition of field already present and the field of ME. If the net electric field is near criticality originally (think as analog neuronal membrane) and becomes over-critical, quantal Becker current starts to flow and the machinery responsible for gene activation is activated.

This means also the activation of metabolic machinery since the acceleration of electrons in the electric field gives them energy making possible a transfer to smaller space-time sheets where they form Cooper pair like states with negentropic entanglement. Metabolic energy corresponds to zero point kinetic energy and negentropic entanglement is relevant from the point of view of consciousness: in the case of healing understood as a regeneration of negentropic resources this aspect is especially important. This mechanism generates high energy phosphate bonds in ATP and the decay ATP $\rightarrow$ ADP liberates the metabolic energy and destroys the negentropic entanglement possibly associated with ATP so that the second law in generalized form (see `http://tinyurl.com/yakmqhz6`) [L5] allowing local generation of genuine negentropy (but assigned to information carried by entanglement defining a quantum rule) wins after all.

It could also happen that the decay of ATP generates dark photon or photons absorbed by cyclotron condensate at magnetic flux tube. The excited state is non-local single particle excitation and involves very simple negentropic entanglement between the particles of the condensate. In this case the negentropy of ATP would be transformed to the negentropy of the magnetic flux tube or even several of them if large value of Planck constant is associated with the photon. This mechanism could allow the generation of negentropic entanglement associated with attention. The storage of metabolic energy in photosynthesis could involve similar excitation of cyclotron state at the first step. The most plausible candidate is cyclotron condensate for electron Cooper pairs. Also electrons filling state up to some Fermi energy could be in question. In this case the excitations would be excitation in longitudinal degrees of freedom of the flux tube generating current.

3.8 Exotic Color And Electro-Weak Interactions

The finding of a correct interpretation of long ranged electro-weak and color gauge fields predicted by classical TGD has been the basic stumbling block for the development of the understanding of TGD Universe and it took about 27 years before the time was ripe to see that TGD predicts entire fractal hierarchy of scaled down copies of standard model physics so that TGD Universe can be seen as a kind of inversion of Mandelbrot fractal for which each new bird eye of view reveals new structures assignable to higher levels in the hierarchy of consciousness.

3.8.1 Long Range Classical Weak And Color Gauge Fields AsCorrelates For Dark Massless Weak Bosons

Long ranged electro-weak gauge fields are unavoidably present when the dimension D of the CP_2 projection of the space-time sheet is larger than 2. Classical color gauge fields are non-vanishing for all non-vacuum extremals. This poses deep interpretational problems. If ordinary quarks and leptons are assumed to carry weak charges fed to larger space-time sheets within electro-weak length scale, large hadronic, nuclear, and atomic parity breaking effects, large contributions of the classical Z^0 force to Rutherford scattering, and strong isotopic effects, are expected. If weak charges are screened within electro-weak length scale, the question about the interpretation of long ranged classical weak fields remains.

Various interpretations for the long ranged classical electro-weak fields

During years I have discussed several solutions to the problems listed above.

Option I: The trivial solution of the constraints is that Z^0 charges are neutralized at electro-weak length scale. The problem is that this option leaves open the interpretation of classical long ranged electro-weak gauge fields unavoidably present in all length scales when the dimension for the CP_2 projection of the space-time surface satisfies $D > 2$.

Option II: Second option involves several variants but the basic assumption is that nuclei or even quarks feed their Z^0 charges to a space-time sheet with size of order neutrino Compton length. The large parity breaking effects in hadronic, atomic, and nuclear length scales is not the only difficulty. The scattering of electrons, neutrons and protons in the classical long range Z^0 force contributes to the Rutherford cross section and it is very difficult to see how neutrino screening could make these effects small enough. Strong isotopic effects in condensed matter due to the classical Z^0 interaction energy are expected. It is far from clear whether all these constraints can be satisfied by any assumptions about the structure of topological condensate.

Option III: During 2005 (27 years after the birth of TGD!) third option solving the problems emerged based on the progress in the understanding of the basic mathematics behind TGD.

In ordinary phase the Z^0 charges of elementary particles are indeed neutralized in intermediate boson length scale so that the problems related to the parity breaking, the large contributions of classical Z^0 force to Rutherford scattering, and large isotopic effects in condensed matter, trivialize.

Classical electro-weak gauge fields in macroscopic length scales are identified as space-time correlates for the gauge fields created by dark matter, which corresponds to a macroscopically quantum coherent phase for which elementary particles possess complex conformal weights such that the net conformal weight of the system is real.

In this phase $U(2)_{ew}$ symmetry is not broken below the scaled up weak scale except for fermions so that gauge bosons are massless below this length scale whereas fermion masses are essentially the same as for ordinary matter. By charge screening gauge bosons look massive in length scales much longer than the relevant p-adic length scale. The large parity breaking effects in living matter (chiral selection for bio-molecules) support the view that dark matter is what makes living matter living.

Classical color gauge fields

Classical long ranged color gauge fields always present for non-vacuum extremals are interpreted as space-time correlates of gluon fields associated with dark copies of hadron physics. It seems that this picture is indeed what TGD predicts. A very special feature of classical color fields is that the holonomy group is Abelian. This follows directly from the expression $g^A_{\alpha\beta} \propto H^A J_{\alpha\beta}$ of induced gluon fields in terms of Hamiltonians H^A of color isometries and induced Kähler form $J_{\alpha\beta}$. This means that classical color magnetic and electric fluxes reduce to the analogs of ordinary magnetic fluxes appearing in the construction of WCW geometry [K30].

By a local color rotation the color field can be rotated to a fixed direction so that genuinely Abelian field would be in question apart from the possible presence of gauge singularities making impossible a global selection of color direction. These singularities could be present since Kähler form defines a magnetic monopole field. An interesting question inspired by quantum classical correspondence is what the Abelian holonomy tells about the sources of color gauge fields and color confinement.

For instance, could Abelian holonomy mean that colored gluons (and presumably also other colored particles) do not propagate in the p-adic length scale considered? Color neutral gluons would propagate but since also their sources must be color neutral, they should have vanishing net color electric fluxes. This form of confinement would allow those states of color multiplets which have vanishing color charges and obviously symmetry breaking down to $U(1) \times U(1)$ would be in question. This would serve as a signal for monopole confinement which would not exclude higher multipoles for the Abelian color fields. This kind of fields appear in the TGD based model for nuclei as nuclear strings bound together by color flux tubes [K97]. In the sequel the model for nuclear color force is briefly discussed in order to give an idea about how the dark color forces might act also in longer length scales.

3.8.2 Dark Color Force As A Space-Time Correlate For The Strong Nuclear Force?

Color confinement suggests a basic application of the basic criteria for the transition to large $\hbar$ phase. The obvious guess is that valence quarks are dark [K38, K36]. Dark matter phase for quarks does not change the lowest order classical strong interaction cross sections but reduces dramatically higher order perturbative corrections and resolves the problems created by the large value of QCD coupling strength in the hadronic phase.

The challenge is to understand the strong binding solely in terms of dark QCD with large value of $\hbar$ reducing color coupling strength of valence quarks by factor $1/r \simeq 2^{-k_d}$. The best manner to introduce the basic ideas is as a series of not so frequently asked questions and answers.

Rubber band model of strong nuclear force as starting point

The first question is what is the vision for nuclear strong interaction that one can start from. The sticky toffee model of Chris Illert [C4] is based on the paradox created by the fact alpha particles can tunnel from the nucleus but that the reversal of this process in nuclear collisions does not occur. Illert proposes a classical model for the tunnelling of alpha particles from nucleus based on dynamical electromagnetic charge. Illert is forced to assume that virtual pions inside nuclei have considerably larger size than predicted by QCD and the model. Strikingly, the model favors fractional alpha particle charges at the nuclear surface. The TGD based interpretation would be based on the identification of the rubber bands of Illert as long color bonds having exotic light quark and anti-quark at their ends and connecting escaping alpha particle to the mother nucleus. The challenge is to give meaning to the attribute “exotic”.

How the darkness of valence quarks can be consistent with the known sizes of nuclei?

The assumption about darkness of valence quarks in the sense of of large $\hbar$ ($\hbar_s = \hbar/v_0$) is very natural if one takes the basic criterion for darkness seriously. The obvious question is how the dark color force can bind the nucleons to nuclei of ordinary size if the strength of color force is v_0 and color sizes of valence quarks are about $L(129)$?

It seems also obvious that $L(107)$ in some sense defines the size for nucleons, and somehow this should be consistent with scaled up size $L(k_{eff} = 129)$ implied by the valence quarks with large $\hbar$. The proposal of [K38, K36] inspired by RHIC findings [C20] is that valence quarks are dark in the sense of having large value of $\hbar$ and thus correspond to $k_{eff} = 129$ whereas sea quarks correspond to ordinary value for $\hbar$ and give rise to the QCD size $\sim L(107)$ of nucleon.

If one assumes that the typical distances between sea quark space-time sheets of nucleons is obtained by scaling down the size scale of valence quarks, the size scale of nuclei comes out correctly.

Valence quarks and exotic quarks cannot be identical

The hypothesis is that nucleons contain or there are associated with them pairs of exotic quarks and flux tubes of color field bodies of size $\sim L(129)$ connecting the exotic quark and anti-quark in separate nuclei. Nucleons would be structures with the size of ordinary nucleus formed as densely packed structures of size $L(129)$ identifiable as the size of color magnetic body.

The masses of exotic quarks must be however small so that they must differ from valence quarks. The simplest possibility is that exotic quarks are not dark but p-adically scaled down versions of sea quarks with ordinary value of $\hbar$ having $k = 127$ so that masses are scaled down by a factor 2^{-10}.

Energetic considerations favor the option that exotic quarks associate with nucleons via the $k_{eff} = 111$ space-time sheets containing nucleons and dark quarks. Encouragingly, the assumption that nucleons topologically condense at the weak $k_{eff} = 111$ space-time sheet of size $L(111) \simeq 10^{-14}$ m of exotic quarks predicts essentially correctly the mass number of the highest known super-massive nucleus. Neutron halos are outside this radius and can be understood in terms color Coulombic binding by dark gluons. Tetraneutron can be identified as alpha particle containing two negatively charged color bonds.

What determines the binding energy per nucleon?

The binding energies per nucleon for $A \geq 4$ to not vary too much from 7 MeV but the lighter nuclei have anomalously small binding energies. The color bond defined by a color magnetic flux tube of length $\sim L(k = 127)$ or $\sim L(k_{eff} = 129)$ connecting exotic quark and anti-quark in separate nucleons with scaled down masses $m_q(dark) \sim xm_q$, with $x = 2^{-10}$ for option for $k = 127$, is a good candidate in this respect. Color magnetic spin-spin interaction would give the dominant contribution to the interaction energy as in the case of hadrons. This interaction energy is expected to depend on exotic quark pair only. The large zero point kinetic energy of light nuclei topologically condensed at $k_{eff} = 111$ space-time sheet having possible identification as the dark variant of $k = 89$ weak space-time sheet explains why the binding energies of D and ^3He are anomalously small.

What can one assume about the color bonds?

Can one allow only quark anti-quark type color bonds? Can one allow the bonds to be also electromagnetically charged as the earlier model for tetra-neutron suggests (tetra-neutron would be alpha particle containing two negatively charged color bonds so that the problems with the Fermi statistics are circumvented). Can one apply Fermi statistics simultaneously to exotic quarks and anti-quarks and dark valence quarks?

Option I: Assume that exotic and dark valence quarks are identical in the sense of Fermi statistics. This assumption sounds somewhat non-convincing but is favored by p-adic mass calculations supporting the view that the p-adic mass scale of hadronic quarks can vary. If this hypothesis holds true at least effectively, very few color bonds from a given nucleon are allowed by statistics and there are good reasons to argue that nucleons are arranged to highly tangled string like structures filling nuclear volume with two nucleons being connected by color bonds having of length of order $L(129)$. The organization into closed strings is also favored by the conservation of magnetic flux.

The notion of nuclear string is strongly supported by the resulting model explaining the nuclear binding energies per nucleon. It is essential that nucleons form what might be called nuclear strings rather than more general tangles. Attractive p-p and n-n bonds must correspond to colored ρ_0 type bonds with spin one and attractive p-n type bonds to color singlet pion type bonds. The quantitative estimates for the spin-spin interaction energy of the lightest nuclei lead to more precise estimates for the lengths of color bonds. The resulting net color quantum numbers must be compensated by dark gluon condensate, the existence of which is suggested by RHIC experiments [C20]. This option is strongly favored by the estimate of nuclear binding energies.

Option II: If Fermi statistics is not assumed to apply in the proposed manner, then color magnetic flux tubes bonds between any pair of nucleons are possible. The identification of color isospin as strong isospin still effective removes color degree of freedom. As many as 8 color tubes can leave the nucleus if exotic quarks and anti-quarks are in the same orbital state and a cubic lattice like structure would become possible. This picture would be consistent with the idea that in ordinary field theory all particle pairs contribute to the interaction energy. The large scale of the magnetic flux tubes would suggest that the contributions cannot depend much on particle pair.

The behavior of the binding energies favors strongly the idea of nuclear string and reduces this option to the first one.

What is the origin of strong force and strong isospin?

Here the answer is motivated by the geometry of CP_2 allowing to identify the holonomy group of electro-weak spinor connection as U(2) subgroup of color group. Strong isospin group SU(2) is identified as subgroup of isotropy group U(2) for space-time surfaces in a sub-theory defined by $M^4 \times S^2$, S^2 a homologically non-trivial geodesic sphere of CP_2 and second factor of $U(1) \times U(1)$ subgroup of the holonomies for the induced Abelian gauge fields corresponds to strong isospin component I_3. The extremely tight correlations between various classical fields lead to the hypothesis that the strong isospin identifiable as color isospin I_3 of exotic quarks at the ends of color bonds attached to a given nucleon is identical with the weak isospin of the nucleon. Note that this does not require that exotic and valence quarks are identical particles in the sense of Fermi statistics.

Does the model explain the strong spin orbit coupling ($L \cdot S$ force)? This force can be identified as an effect due to the motion of fermion string containing the effectively color charged nucleons in the color magnetic field $v \times E$ induced by the motion of string in the color electric field at the dark $k = 107$ space-time sheet.

How the phenomenological shell model with harmonic oscillator potential emerges?

Nucleus can be seen as a collection of of long color magnetic flux tubes glued to nucleons with the mediation of exotic quarks and anti-quarks. If nuclei form closed string, as one expects in the case of Fermi statistics constraint, also this string defines a closed string or possibly a collection of linked and knotted closed strings. If Fermi statistics constraint is not applied, the nuclear strings form a more complex knotted and linked tangle. The stringy space-time sheets would be the color magnetic flux tubes connecting exotic quarks belonging to different nucleons.

The color bonds between the nucleons are indeed strings connecting them and the averaged interaction between neighboring nucleons in the nuclear string gives in the lowest order approximation 3-D harmonic oscillator potential although strings have $D = 2$ transversal degrees of freedom. Even in the case that nucleons for nuclear strings and thus have only two bonds to neighbors the average force around equilibrium position is expected to be a harmonic force in a good approximation. The nuclear wave functions fix the restrictions of stringy wave functionals to the positions of nucleons at the nuclear strings. Using M-theory language, nucleons would represent branes connected by color magnetic flux tubes representing strings whose ends co-move with branes.

Which nuclei are the most stable ones and what is the origin of magic numbers?

$P = N$ closed strings correspond to energy minima and their deformations obtained by adding or subtracting nucleons in general correspond to smaller binding energy per nucleon. Thus the observed strong correlation between P and N finds a natural explanation unlike in the harmonic oscillator model. For large values of A the generation of dark gluon condensate and corresponding color Coulombic binding energy favors the surplus of neutrons and the generation of neutron halos. The model explains also the spectrum of light nuclei, in particular the absence of pp, nn, ppp, and nnn nuclei.

In the standard framework spin-orbit coupling explains the magic nuclei and color Coulomb force gives rise to this kind of force in the same manner as in atomic physics context. Besides the standard magic numbers there are also non-standard ones (such as $Z, N = 6, 12$) if the maximum of binding energy is taken as a definition of magic, there are also other magic numbers than the standard ones. Hence can consider also alternative explanations for magic numbers. The geometric view about nucleus suggests that the five Platonic regular solids might defined favor nuclear configurations and it indeed turns that they explain non-standard magic numbers for light nuclei.

New magic nuclei might be obtained by linking strings representing doubly magic nuclei. An entire hierarchy of linkings becomes possible and could explain the new magic numbers 14, 16, 30, 32 discovered for neutrons [C2]. Linking of the nuclear strings could be rather stable by Pauli Exclusion Principle. For instance, ^{16}O would corresponds to linked ^4He and ^{12}C nuclei. Higher magic numbers $28, 50, ...$ allow partitions to sums of lower magic numbers which encourages to consider the geometric interpretation as linked nuclei. p-Adic length scale hypothesis in turn suggest the existence of magic numbers coming as powers of 2^3.

3.8.3 How Brain Could Deduce The Position And Velocity Of An Object Of Perceptive Field?

The basic degrees of freedom for mind like space-time sheets can be regarded as parameters specifying color quantization axes and spin quantization axis. The parameters characterizing the choices of the color quantization axes define 3+3-dimensional symplectic flag-manifold $F_3 = SU(3)/U(1) \times U(1)$ whereas the parameters fixing spin-quantization axes define two-dimensional flag-manifold $F_2 = SU(1)/U(1) = S^2$, which is identical to two-sphere and whose point characterizes some orientation vector. A mathematically attractive identification of the flag manifold F_3 is as a representation for the possible positions and velocities of an object of the perceptive field whereas F_2 could represent some orientation, say ear-to-ear orientation axis. This identification, if correct, provides additional support for the uniqueness of the choice of the embedding space $H = M^4_+ \times CP_2$. Amazingly, the model of honeybee dance by Barbara Shipman leads to the identification of the flag manifold F_3 as a fundamental mathematical structure associated with the cognition of the honeybee.

Without a good physical justification this kind of identification is however ad hoc. Fortunately, the following argument makes it possible to understand why F_3 should code the position and the velocity of the objects of the perceptive field.

1. The time development by quantum self-organization is expected to lead to well defined asymptotic values of (P, Q) coordinates during each wake-up period of the mind like space-time sheet representing object of the perceptive field and in self-state.

2. The crucial observation is that classical em and Z^0 fields are accompanied by classical color fields in TGD. Color rotations rotate the color field in color space whereas induced Kähler form remains unchanged. Most importantly: classical em and Z^0 fields do not remain invariant under color rotations as they would remain in standard model. This leads to the idea that different (P, Q) values obtained by color rotations of cognitive and neuronal space-time sheets correspond to slightly different membrane potentials and that it is the dependence of the membrane potential on the position and velocity of the object of the perceptive field, which leads to (P, Q) coding.

3. An observation not directly related to (P, Q) coding is that classical em and color fields induce tiny color polarization at quark level leading to color polarization of nuclei: this color polarization could provide the quantum correlate for the color quale. The representation of color in this manner however requires that (P, Q) are same for all neurons in the perceptive field so that the coding of positions and velocities and color are mutually exclusive. Positions and velocities and color are indeed represented by different regions of cortex.

4. Color rotation induces motion in F_3 rotating color quantization axes and leaving the induced Kähler field invariant so that absolute minima of Kähler action are mapped to absolute minima and zero modes are not changed. Classical Z^0 and em fields are however *not* invariant under color rotations. How classical em and Z^0 depend on Kähler form becomes clear from the following formulas:

$$\begin{aligned}
\gamma &= 3J - \frac{1}{2}sin^2\theta_W Z^0 \ , \\
Z^0 &= 2J + 4e^0 \wedge e^3 \ , \\
J &= 2(e^0 \wedge e^3 + e^1 \wedge e^2) \ .
\end{aligned} \tag{3.8.1}$$

Here J denotes Kähler form invariant under color rotations and e^k denote vierbein vectors of CP_2. $e^0 \wedge e^3$ denotes the part of Z^0, which is not invariant under color rotations. From these formulas it is evident that classical photon field is not in general invariant since it is a superposition of the induced Kähler field and classical Z^0 field and reduces to induced Kähler field only when the Weinberg angle vanishes: the physical value of the Weinberg angle is about $sin^2(\theta_W) = 1/4$. This means that various points (P, Q) of (3+3)-dimensional F_3 indeed correspond to different classical Z^0 fields and classical em fields.

5. There is however an important exception to this picture. If CP_2 projection belongs to geodesic sphere S^2, the field equations reduces to those for $X^4 \subset M^4 \times S^2$. For space-time sheets for which CP_2 projection is $r = \infty$ homologically non-trivial geodesic sphere of CP_2 one has

$$\gamma = (\frac{3}{4} - \frac{sin^2(\theta_W)}{2})Z^0 \simeq \frac{5Z^0}{8}$$

as the explicit study of $r = \infty$ geodesic sphere shows (see the appendix of the book). The induced W fields vanish in this case and they vanish also for all geodesic spheres obtained by $SU(3)$ rotation. There are excellent reasons to believe that also the relationship between Z^0 and γ is $SU(3)$ invariant so that there would be no mixing between em and Z^0 fields. For homologically trivial geodesic spheres γ and Z^0 vanish and only W fields are non-vanishing. This kind of MEs would naturally correspond to W MEs.

For $D > 2$-dimensional CP_2 projection the situation changes. MEs have always 2-D CP_2 projection field equations and field equations are satisfied without assuming that CP_2 projection is a geodesic sphere and in this case one can hope of getting mixing of γ and Z^0 also in this case perhaps characterizable in terms of the value of the Weinberg angle. Also W fields can be present in this case.

6. Assuming that the values of (P, Q) coordinates are the same for the neuronal group representing an object of the perceptive field and the mind like space-time sheet associated with it (this could be forced by the wormhole contacts), (P, Q) coding for the positions and velocities for the objects of the perceptive field follows if these observables are coded into the properties of the classical Z^0 field associated with the neuronal membrane. This seems plausible since a change of the classical Z^0 field implies a change of the classical em field if the induced Kähler field remains invariant (as is natural). Thus the problem of understanding (P, Q) coding for position and velocity reduces to the problem of understanding why the position and velocity should affect some natural em field associated with cell membrane. Obviously membrane resting potential is an excellent candidate for this em field.

7. The dependence of the value of the membrane resting potential for the representation of an object of the perceptive field on the the position and velocity of the object is natural. For instance, it is advantageous for the neurons representing object near to the observer to be nearer to the criticality for firing. Thus the membrane potential must be reduced by a suitable color rotation and effective code position of the object to Q coordinates. Also, when the object moves towards/away from the observer, the resting potential should be reduced/increased and this means that velocity is coded to P value (note that there is infinite number of symplectic coordinates at use). From these correlations it is quite plausible that (P, Q) coding could be a result of natural selection. Of course, the coding of position and velocity to (P, Q) values need not be one-to-one. For instance, simple organisms are sensitive for velocity only and some organisms experience world as 2-dimensional.

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Chapter 4

Wormhole Magnetic Fields

4.1 Introduction

Topological field quantization has turned out to be fundamental for the understanding of quantum TGD and TGD inspired theory of consciousness. What makes topological field quantization so important is that it provides very precise classical representation for the quantum aspects of the theory. Even virtual particles have geometric counterparts. In TGD the sign of the classical energy correlates with the time orientation of the space-time sheet and this makes possible pairs of space-time sheets of finite duration having vanishing total energy. This suggest an astonishingly simple mechanism for the formation of cognitive representations: direct mimicry in which classical fields in some region of the material space-time sheet are realized at the two mind-like space-time sheets of opposite time orientation! This realization would make physicist's universe analogous to the computer scientist's universe filled with computers emulating each other. Concerning the understanding of how intelligent consciousness is realized, the implications would be highly nontrivial.

The fact that em fields oscillating with multiples of the cyclotron frequencies of various charged particles in Earth's magnetic fields have effects on living matter [J25] could indeed mean that biomatter mimics Earth's magnetic field by forming double sheeted structures, wormhole magnetic fields, with magnetic field strength equal to that of Earth's magnetic field. This observation could serve as a good motivation for the modelling of wormhole magnetic fields. This was not the original motivation for studying wormhole magnetic fields. Rather, it was the modelling of homeopathy in terms mind-like space-time sheets, which led to the discovery of the astonishing possibility of a direct mimicry performed by mind-like space-time sheets. Note that also more abstract cognitive representations are possible. In particular, various oscillation frequencies of material space-time sheets could be transferred to mind-like space-time sheets and the counterparts of FM and AM modulation would provide obvious cognitive representations.

Topological field quantization originates from the fact that given classical gauge field configuration does not allow global representation as an induced gauge field but space-time splits into separate regions, topological field quanta. Typically, magnetic field reduces to a bundle of disjoint *flux tubes* flowing along field lines of classical field, which in TGD context are cylindrical regions of 3-space with outer boundaries. There is no doubt about the fundamental importance of topological field quanta for biosystems if TGD is correct and the natural working hypothesis is that topologically quantized classical gauge field configurations belong to the basic tools of biocontrol and that the vacuum quantum numbers characterizing topological field quanta (for the definition of vacuum quantum numbers see the Appendix) carry bio-information.

It has also become clear, that the closely related concepts of *many-sheeted space-time* and *charged wormhole* play crucial role in biosystems. Wormholes feed gauge fluxes from a smaller sheet of 3-space to a larger one and are located near the boundary of the smaller 3-space sheet and have size of order CP_2 length of order 10^4 Planck lengths as do also ordinary elementary particles. Not only electromagnetic but also Z^0 wormholes are possible in TGD since long range classical Z^0 fields are unavoidable in TGD context. Wormhole throat can have also magnetic charge. Furthermore, the topology of the wormhole throat, being characterized by the genus of the

2-surface in question, gives rise to a degeneracy analogous to the family replication of elementary fermions.

Wormhole concept leads naturally to the concept of *wormhole flux tube*, which by assumption contains no ordinary matter inside it and is forced by Maxwell equations to be a *hollow cylinder*. Maxwell's equations require rotating charge carrier densities with opposite total charges on the inner and outer boundaries of this cylinder. Since ordinary charges are excluded, the only possibility is that these charge carries are charged wormholes. Since the wormhole behaves like a gauge charge $\pm Q$ on the two space-time sheets respectively, there is return flux on the second space-time sheet. Wormhole flux tubes need not be closed unlike ordinary flux tubes: at the end point magnetic flux just flows from "upper" space-time sheet to the "lower" space-time sheet via magnetic wormhole behaving as magnetic charge $\pm Q_m$ on the two space-time sheets respectively. Charged wormhole flux tubes can form arbitrary complicated net like structures. Since wormholes form *BE condensate* and behave as super conductor, the classical field is transformed in TGD context to a macroscopic quantum system, *wormhole magnetic field*. It has become clear that electronic and neutrino superconductivity might play fundamental role in biosystems: it might be even possible to identify the quantum correlates of sensory qualia as coherent photons and gravitons, wormhole BE condensate and BE condensates of electronic and neutrino Cooper pairs. What is important is that wormhole magnetic fields seem to provide a topological representation for the defects of fermionic super conductors.

Quantum antenna hypothesis states that the light-like vacuum currents associated with microtubules, and possibly also other linear structures, serve as sources of quantum coherent photon fields [K70] , in particular of bio-photons. The phenomenon of sonoluminescence has an explanation in terms of light-like vacuum currents underlying the quantum antenna hypothesis and that microtubular diameter provides a natural intrinsic length scale of hydrodynamics of water. One of the many challenges is to understand how wormholes and coherent photons interact. In this chapter a model for this interaction is proposed. The model leads to possible explanations of *Comorosan effect* [I92, I33] and *phantom DNA effect* [I46, I109]. Also the effect of homeopathy could reduce to that of mind-like space-time sheets associated with the drug if these mind-like space-time sheets mimic directly the classical gauge field structure of the drug.

The first version of this chapter was written for almost two decades ago and some interpretations have changed since then. It was argued that two purely TGD based concepts: topological field quantization and wormhole BE condensate are fundamental for the understanding of biosystems. There is not reason to modify this claim. The ideas about the physical interpretation of wormhole contacts have however developed since then dramatically: in the recent formulation of the theory wormhole contacts define basic building bricks of elementary particles. Hierarchy of Planck constants assigned with dark matter is second new notion and this might allow to see wormhole BE-condensates as BE-condensates of dark variants of ordinary particles.

The concept of wormhole magnetic field is proposed as a possible explanation for claimed psychokinetic effects (PK). Topologically quantized wormhole magnetic field, being a macroscopic quantum system, can give rise to PK effect via *magnetic levitation*, if external object is wormhole super conductor and if the density of charged wormholes on its boundary is sufficiently high to generate Meissner effect. This same structure could enlarge DNA and other basic structures to macroscopic quantum systems with size much larger than the basic object consisting of ordinary matter. One could even imagine that the structure of DNA sequences could be coded into the structure of the topologically quantized magnetic field created by it.

An alternative model of psychokinesis is based on the possibility of space-time sheets having negative time orientation and carrying therefore negative classical energy. It is not clear whether the space-time sheets associated with the wormhole magnetic fields could have opposite time orientations. This kind of mechanism of energy production might explain claimed poltergeist type effects involving spontaneous gain of kinetic energy. Many-sheeted space-time concept makes possible also psychokinesis based on levitation: what is needed that subsystem is able to topologically condense to a sufficiently large space-time sheet carrying very weak gravitational fields.

This chapter describes the view about wormhole contacts as it was for more than decade ago. The recent identification of wormhole contacts is as bosons with positive and negative energy fermion and anti-fermion at the opposite light-like throats of the contact. This allows to identify also virtual gauge bosons as pairs of on mass shell fermions. Virtual fermions could correspond to wormhole contacts with second contact identifiable as Fock vacuum. Also super-symmetric partners of these states obtained by applying fermionic oscillator operator algebra correspond to particle like states. Therefore wormhole contacts might not represent completely new physics and be identifiable as gauge boson like or Higgs like states. If the wormhole throat carries magnetic flux it could define a dyonlike partner of ordinary gauge boson or Higgs.

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` [L13].

4.2 Basic Conceptual Framework

The notions of topological condensate and p-adic length scale hierarchy are in a central role in TGD and for a long time it seemed that the physical interpretation of these notions is relatively straightforward. The evolution of number theoretical ideas however forced to suspect that the implications for physics might be much deeper and involve not only a solution to the mysteries of dark matter but also force to bring basic notions of TGD inspired theory of consciousness. At this moment the proper interpretation of the mathematical structures involving typically infinite hierarchies generalizing considerably the mathematical framework of standard physics is far from established so that it is better to represent just questions with some plausible looking answers.

4.2.1 Basic Concepts

It is good to discuss the basic notions before discussing the definition of gauge charges and gauge fluxes.

CP_2 type vacuum extremals

CP_2 type extremals behave like elementary particles (in particular, light-likeness of M^4 projection gives rise to Virasoro conditions). CP_2 type vacuum extremals have however vanishing four-momentum although they carry classical color charges. This raises the question how they can gain elementary particle quantum numbers.

In topological condensation of CP_2 type vacuum extremal a light-like causal horizon is created. Number theoretical considerations strongly suggest that the horizon carries elementary particle numbers and can be identified as a parton. The quantum numbers or parton would serve as sources of the classical gauge fields created by the causal horizon.

In topological evaporation CP_2 type vacuum extremal carrying only classical color charges is created. This would suggest that the scattering of CP_2 type vacuum extremals defines a topological quantum field theory resulting as a limit of quantum gravitation (CP_2 is gravitational instanton) and that CP_2 type extremals define the counterparts of vacuum lines appearing in the formulation of generalized Feynman diagrams.

Wormhole contacts as parton pairs

The earlier view about wormhole (#) contacts (see **Fig.** `http://tgdtheory.fi/appfigures/wormholecontact.jpg` or **Fig. ??** in the appendix of this book) as passive mediators of classical gauge and gravitational fluxes is not quite correct. The basic modification is due to the fact that one can assign parton or parton pair to the # contact so that it becomes a particle like entity. This means that an entire p-adic hierarchy of new physics is predicted.

1. Formally # contact can be constructed by drilling small spherical holes S^2 in the 3-surfaces involved and connecting the spherical boundaries by a tube $S^2 \times D^1$. For instance, CP_2 type extremal can be glued to space-time sheet with Minkowskian signature or space-time sheets with Minkowskian signature can be connected by # contact having Euclidian signature of the induced metric. Also more general contacts are possible since S^2 can be replaced with a 2-surface of arbitrary genus and family replication phenomenon can be interpreted in terms of the genus.

   The # contact connecting two space-time sheets with Minkowskian signature of metric is accompanied by two “elementary particle horizons”, which are light-like 3-surfaces at which the induced 4-metric becomes degenerate. Since these surfaces are causal horizons, it is not clear whether # contacts can mediate classical gauge interactions. If there is an electric gauge flux associated with elementary particle horizon it tends to be either infinite by the degeneracy of the induced metric. It is not clear whether boundary conditions allow to have finite gauge fluxes of electric type. A similar difficulty is encountered when one tries to assign gravitational flux to the # contact: in this case even the existence of flux in non-singular case is far from obvious. Hence the naïve extrapolation of Newtonian picture might not be quite correct.

2. Number theoretical considerations suggests that the two light-like horizons associated with # contacts connecting space-time sheets act as dynamical units analogous to shock waves or light fronts carrying quantum numbers so that the identification as partons is natural. Quantum holography would suggest itself in the sense that the quantum numbers associated with causal horizons would determine the long range fields inside space-time sheets involved.

3. # contacts can be modelled in terms of CP_2 type extremals topologically condensed simultaneously to the two space-time sheets involved. The topological condensation of CP_2 type extremal creates only single parton and this encourages the interpretation as elementary particle. The gauge currents for CP_2 type vacuum extremals have a vanishing covariant divergence so that there are no conserved charges besides Kähler charge. Hence electro-weak gauge charges are not conserved classically in the region between causal horizons whereas color gauge charges are. This could explain the vacuum screening of electro-weak charges at space-time level. This is required since for the known solutions of field equations other than CP_2 type extremals vacuum screening does not occur.

4. In the special case space-time sheets have opposite time orientations and the causal horizons carry opposite quantum numbers (with four-momentum included) the # contact would serve the passive role of flux mediator and one could assign to the contact generalized gauge fluxes as quantum numbers associated with the causal horizons. This is the case if the contact is created from vacuum in topological condensation so that the quantum numbers associated with the horizons define naturally generalized gauge fluxes. Kind of generalized quantum dipoles living in two space-times simultaneously would be in question. # contacts in the ground state for space-time sheets with opposite time orientation can be also seen as zero energy parton-antiparton pairs bound together by a piece of CP_2 type extremal.

5. When space-time sheets have same time orientation, the two-parton state associated with the # contact has non-vanishing energy and it is not clear whether it can be stable.

$\#_B$ contacts as bound parton pairs

Besides # contacts also flux tubes (JABs, $\#_B$ contacts) are possible. They can connect outer boundaries of space-time sheets or the boundaries of small holes associated with the interiors of two space-time sheets which can have Minkowskian signature of metric and can mediate classical gauge fluxes and are excellent candidates for mediators of gauge interactions between space-time sheet glued to a larger space-time sheet by topological sum contacts and join along boundaries contacts. The size scale of the causal horizons associated with parton pairs can be arbitrary whereas the size scale of # contacts is given by CP_2 radius.

Consider first the original vision about JABs. The original belief was that the existence of the holes for real space-time surfaces is a natural consequence of the induced gauge field concept: for sufficiently strong gauge fields the imbeddability of gauge field as an induced gauge field fails and hole in space-time appears as a consequence. The holes connected by $\#_B$ contacts obey field equations, and a good guess is that they are light-like 3-surfaces and carry parton quantum numbers. This would mean that both # and $\#_B$ contacts allow a fundamental description in terms of pair of partons.

Magnetic flux tubes provide a representative example of $\#_B$ contact. Instead of $\#_B$ contact also more descriptive terms such as join along boundaries bond (JAB), color bond, and magnetic flux tube are used. $\#_B$ contacts serve also as a space-time correlate for bound state formation and one can even consider the possibility that entanglement might have braiding of bonds defined by # contacts as a space-time correlate [K6].

It seems difficult to exclude flux tubes between between holes associated with the two space-time sheets at different levels of p-adic hierarchy. If these contacts are possible, a transfer of conserved gauge fluxes would be possible between the two space-time sheets and one could speak about interaction in conventional sense.

The most recent TGD view about JABs is different. The recent belief is that boundaries- and jus JABs- are not allowed by the boundary conditions: space-time sheets with boundary are replaced with their double covers. Furthermore, elementary particles and also larger systems correspond to space-time regions which as lines of generalized Feynman diagrams have Euclidian signature of the induced metric. This suggests that magnetic flux tubes as deformations of cosmic strings have Euclidian signature of metric too. This is quite possible and in the simplest situation would require that string world sheet has Euclidian signature of the induced metric. JABs in this sense would serve as correlates of quantum entanglement between system that they connect together.

Double cover property means that JABs identified as Kähler magnetic flux tubes have cross section, which are closed surfaces, and thus can carry quantized Kähler magnetic flux. These flux tubes would provide correlates for the magnetic fields known to exist in cosmological scales but no possible in standard cosmology due to the fact that needed currents should be coherent in long scales. For monopole fluxes no currents are needed.

Wormhole contacts as bosons and their super partners

The original interpretation of wormhole contacts (see **Fig.** `http://tgdtheory.fi/appfigures/wormholecontact.jpg` or **Fig. ??** in the appendix of this book) was as genuinely new kind of particle like objects. With the emergence of zero energy ontology it gradually became clear that ordinary gauge bosons and Higgs particle and their super partners can be identified as wormhole contacts. Free fermions and their super-partners would be identified as CP_2 type vacuum extremals glued to a space-time sheet with a Minkowskian signature of the induced metric and thus possessing only single wormhole throat identificed as a light-like 3-surface.

This identification has far reaching implications. For instance, off mass shall particles can be interpreted as pairs of on mass shell positive and negative energy states at the opposite throats of the wormhole contact. This representation of virtual particles is crucial for the generalization of twistor formalism to TGD framework [K108].

A possible interpretation of wormhole contacts in living matter is as scaled up variants of bosons having much smaller mass and massless below confinement scale and appropriate p-adic length scale. This would mean the existence of scaled up copies of QCD type physics and electro-weak physics. These phases could be dark and characterized by a large value of Planck constant.

Topological condensation and evaporation

Topological condensation corresponds to a formation of $\#$ or $\#_B$ contacts between space-time sheets. Topological evaporation means the splitting of $\#$ or $\#_B$ contacts. In the case of elementary particles the process changes almost nothing since the causal horizon carrying parton quantum numbers does not disappear. The evaporated CP_2 type vacuum extremal having interpretation as a gravitational instanton can carry only color quantum numbers.

As $\#$ contact splits partons are created at the two space-time sheets involved. This process can obviously generate from vacuum space-time sheets carrying particles with opposite signs of energies and other quantum numbers. Positive energy matter and negative energy anti-matter could be thus created by the formation of $\#$ contacts with zero net quantum numbers which then split to produce pair of positive and negative energy particles at different space-time sheets having opposite time orientations. This mechanism would allow a creation of positive energy matter and negative energy antimatter with an automatic separation of matter and antimatter at space-time sheets having different time orientation. This might resolve elegantly the puzzle posed by matter-antimatter asymmetry.

The creation of $\#$ contact leads to an appearance of radial gauge field in condensate and this seems to be impossible at the limit of infinitely large space-time sheet since it involves a radical instantaneous change in field line topology. The finite size of the space-time sheet can however resolve the difficulty.

If all quantum numbers of elementary particle are expressible as gauge fluxes, the quantum numbers of topologically evaporated particles should vanish. In the case of color quantum numbers and Poincare quantum numbers there is no obvious reason why this should be the case. Despite this the cancellation of the interior quantum numbers by those at boundaries or light-like causal determinants could occur and would conform with the effective 2-dimensionality stating that quantum states are characterized by partonic boundary states associated with causal determinants. This could be also seen as a holographic duality of interior and boundary degrees of freedom [K96].

4.2.2 Gauge Charges And Gauge Fluxes

The concepts of mass and gauge charge in TGD has been a source of a chronic headache. There are several questions waiting for a definite answer. How to define gauge charge? What is the microscopic physics behind the gauge charges necessarily accompanying long range gravitational fields? Are these gauge charges quantized in elementary particle level? Can one associate to elementary particles classical electro-weak gauge charges equal to its quantized value or are all electro-weak charges screened at intermediate boson length scale? Is the generation of the vacuum gauge charges, allowed in principle by the induced gauge field concept, possible in macroscopic length scales? What happens to the gauge charges in topological evaporation? Should Equivalence Principle be modified in order to understand the fact that Robertson-Walker metrics are inertial but not gravitational vacua. Or is there some other way to solve the problem.

How to define the notion of gauge charge?

In TGD gauge fields are not primary dynamical variables but induced from the spinor connection of CP_2. There are two ways to define gauge charges.

1. In purely group theoretical approach one can associate non-vanishing gauge charge to a 3-surface of finite size and quantization of the gauge charge follows automatically. This definition should work at Planck length scales, when particles are described as 3-surfaces of CP_2 size and classical space-time mediating long range interactions make no sense. Gauge interactions are mediated by gauge boson exchange, which in TGD has topological description in terms of CP_2 type extremals [L43].

2. Second definition of gauge charge is as a gauge flux over a closed surface. In this case quantization is not obvious nor perhaps even possible at classical level except perhaps for Abelian charges. For a closed 3-surface gauge charge vanishes and one might well argue that this is the case for finite 3-surface with boundary since the boundary conditions might well generate gauge charge near the boundary cancelling the gauge charge created by particles condensed on 3-surface. This would mean that at low energies (photon wavelength large than size of the 3-surfaces) the 3-surfaces in vapor phase look like neutral particles. Only at high energies the evaporated particles would behave as ordinary elementary particles. Furthermore, particle leaves in topological evaporation its gauge charge in the condensate.

   The alternative possibility that the long range $\frac{1}{r^2}$ gauge field associated with particle disappears in the evaporation, looks topologically impossible at the limit when larger space-time sheet has infinite size: only the simultaneous evaporation of opposite gauge charges might be possible in this manner at this limit. Topological evaporation provides a possible mechanism for the generation of vacuum gauge charges, which is one basic difference between TGD and standard gauge theories.

There is a strong temptation to draw a definite conclusion but it is better to be satisfied with a simplifying working hypothesis that gauge charges are in long length scales definable as gauge fluxes and vanish for macroscopic 3-surfaces of finite size in vapor phase. This would mean that the topological evaporation of say electron as an electromagnetically charged particle would not be possible except at CP_2 length scale: in the evaporation from secondary condensation level electron would leave its gauge charges in the condensate. Vapor phase particle still looks electromagnetically charged in length scales smaller than the size of the particle surface if the neutralizing charge density is near (or at) the boundary of the surface and gauge and gravitational interactions are mediated by the exchange of CP_2 type extremals.

In what sense could # contacts feed gauge fluxes?

One can associate with the # throats magnetic gauge charges $\pm Q_i$ defined as gauge flux running to or from the throat. The magnetic charges are of opposite sign and equal magnitude on the two space-time sheets involved. For Kähler form the value of magnetic flux is quantized and non-vanishing only if the $t = constant$ section of causal horizon corresponds to a non-trivial homology equivalence class in CP_2 so that # contact can be regarded as a homological magnetic monopole. In this case # contacts can be regarded as extremely small magnetic dipoles formed by tightly bound # throats possessing opposite magnetic gauge charges. # contacts couple to the difference of the classical gauge fields associated with the two space-time sheets and matter-# contact and # contact-# contact interaction energies are in general non-vanishing.

Electric gauge fluxes through # throat evaluated at the light-like elementary particle horizon X_l^3 tend to be either zero or infinite. The reason is that without appropriate boundary conditions the normal component of electric $F^{tn}\sqrt{(g_4)}/g^2$ either diverges or is infinite since g^{tt} diverges by the effective three-dimensionality of the induced metric at X_l^3. In the gravitational case an additional difficulty is caused by the fact that it is not at all clear whether the notion of gravitational flux is well defined. It is however possible to assign gravitational mass to a given space-time sheets as will be found in the section about space-time description of charge renormalization.

The simplest conclusion would be that the notions of gauge and gravitational fluxes through # contacts do not make sense and that # contacts mediate interactions in a more subtle manner. For instance, for a space-time sheet topologically condensed at a larger space-time sheet the larger space-time sheet would characterize the basic coupling constants appearing in the S-matrix associated with the topologically condensed space-time sheets. In particular, the value of $\hbar$ would characterize the relation between the two space-time sheets. A stronger hypothesis would be that the value of $\hbar$ is coded partially by the Jones inclusion between the state spaces involved. The larger space-time sheet would correspond to dark matter from the point of view of smaller space-time sheet [K118, K38].

One can however try to find loopholes in the argument.

1. It might be possible to pose the finiteness of $F^{tn}\sqrt{g_4}/g^2$ as a boundary condition. The variation principle determining space-time surfaces implies that space-time surfaces are analogous to Bohr orbits so that there are also hopes that gauge fluxes are quantized.

2. Another way out of this difficulty could be based on the basic idea behind renormalization in TGD framework. Gauge coupling strengths are allowed to depend on space-time point so that the gauge currents are conserved. Gauge coupling strengths $g^2/4\pi$ could become infinite at causal horizon. The infinite values of gauge couplings at causal horizons might be a TGD counterpart for the infinite values of bare gauge couplings in quantum field theories. There are however several objections against this idea. The values of coupling constants should depend on space-time sheet only so that the situation is not improved by this trick in CP_2 length scale. Dependence of g^2 on space-time point means also that in the general case the definition of gauge charge as gauge flux is lost so that gauge charges do not reduce to fluxes.

It seems that the notion of a finite electric gauge flux through the causal horizon need not make sense as such. Same applies to the notion of gravitational gauge flux. The notion of gauge flux seems however to have a natural quantal generalization. The creation of a # contact between two space-time sheets creates two causal horizons identifiable as partons and carrying conserved charges assignable with the states created using the fermionic oscillator operators associated with the second quantized induced spinor field. These charges must be of opposite sign so that electric gauge fluxes through causal horizons are replaced by quantal gauge charges. For opposite time orientations also four-momenta cancel each other. The particle states can of course transform by interactions with matter at the two-space-time sheets so that the resulting contact is not a zero energy state always.

This suggests that for gauge fluxes at the horizon are identifiable as opposite quantized gauge charges of the partons involved. If the net gauge charges of # contact do not vanish, it can be said to possess net gauge charge and does not serve as a passive flux mediator anymore. The possibly screened classical gauge fields in the region faraway from the contact define the classical correlates for gauge fluxes. A similar treatment applies to gravitational flux in the case that the time orientations are opposite and gravitational flux is identifiable as gravitational mass at the causal horizon.

Internal consistency would mildly suggest that # contacts are possible only between space-time sheets of opposite time orientation so that gauge fluxes between space-time sheets of same time orientation would flow along $\#_B$ bonds.

Are the gauge fluxes through # and $\#_B$ contacts quantized?

There are good reasons (the fact that the extremals are critical in the sense that they allow an infinite number of deformations with a vanishing second variation of Kähler action plus maximization of the Kähler function) to expect that the gauge fluxes through # (if well-defined) and $\#_B$ contacts are quantized.

The expectation is that the number of critical deformations defining the symmetries is infinite and conformal symmetries are in question. The conformal algebras would form an infinite hierarchy of sub-algebras with generators labelled by integers proportional to an integer $n = 1, 2....$ One would have n conformal equivalence classes of space-time surfaces connecting given 3-surfaces at the boundaries of CD and n would define Planck constant $h_{eff} = n \times h$ labelling the hierarchy of dark matters (see **Fig.** `http://tgdtheory.fi/appfigures/planckhierarchy.jpg` or **Fig. ??** in the appendix of this book).

The most natural guess would be that the unit of electric electromagnetic flux for $\#_B$ contact is 1/3 since this makes it possible for the electromagnetic gauge flux of quarks to flow to larger space-time sheets. Anyons could however mean more general quantization rules [K6]. The quantization of electromagnetic gauge flux could serve as a unique experimental signature for # and $\#_B$ contacts and their currents. The contacts can carry also magnetic fluxes. In the case of $\#_B$ contacts the flux quantization would be dynamical and analogous to that appearing in super conductors.

Hierarchy of gauge and gravitational interactions

The observed elementary particles are identified as CP_2 type extremals topologically condensed at space-time sheets with Minkowski signature of induced metric with elementary particle horizon being responsible for the parton aspect. This suggests that at CP_2 length scale gauge and gravitational interactions correspond to the exchanges of CP_2 type extremals with light-like M^4 projection with branching of CP_2 type extremal serving as the basic vertex as discussed in [L43]. The gravitational and gauge interactions between the partons assignable to the two causal horizons associated with # contact would be mediated by the # contact, which can be regarded as a gravitational instanton and the interaction with other particles at space-time sheets via classical gravitational fields.

Gauge fluxes flowing through the $\#_B$ contacts would mediate higher level gauge and interactions between space-time sheets rather than directly between CP_2 type extremals. The hierarchy of flux tubes defining string like objects strongly suggests a p-adic hierarchy of "strong gravities" with gravitational constant of order $G \sim L_p^2$, and these strong gravities might correspond to gravitational fluxes mediated by the flux tubes.

4.2.3 The Relationship Between Inertial And Gravitational Masses

The understanding of the relationship between TGD and GRT and quantum and classical variants of Equivalence Principle (EP) in TGD have develope rather slowly but the recent picture is rather feasible.

1. The recent view is that EP at quantum level reduces to Quantum Classical Correpondence (QCC) in the sense that Cartan algebra Noether charges assignable to 3-surface in case of Kähler action (inertial charges) are identical with eigenvalues of the quantal variants of Noether charges for Kähler-Dirac action (gravitational charges). The well-definedness of the latter charges is due to the conformal invariance assignable to 2-D surfaces (string world sheets and possibly partonic 2-surfaces) at which the spinor modes are localized in generic case. This localization follows from the condition that em charge has well defined value for the spinor modes. The localization is possibly only for the Kähler-Dirac action and key role

is played by the modification of gamma matrices to Kähler-Dirac gamma matrices. The gravitational four-momentum is thus completely analogous to stringy four-momentum.

2. At classical level EP follows from the interpretation of GRT space-time as effective space-time obtained by replacing many-sheeted space-time with Minkowski space with effective metric determined as a sum of Minkowski metric and sum over the deviations of the induced metrices of space-time sheets from Minkowski metric. Poincare invariance suggests strongly classical EP for the GRT limit in long length scales at least (see **Fig.** `http://tgdtheory.fi/appfigures/manysheeted.jpg` or **Fig.** 9 in the appendix of this book).

ZEO and non-conservation of Poincare charges in Poincare invariant theory of gravitation

In positive energy ontology the Poincare invarance of TGD is in sharpt contrast with the fact that GRT based cosmology predicts non-conservation of Poincare charges (as a matter fact, the definition of Poincare charges is very questionable for general solutions of field equations).

In zero energy ontology (ZEO) all conserved (that is Noether-) charges of the Universe vanish identically and their densities should vanish in scales below the scale defining the scale for observations and assignable to causal diamond (CD). This observation allows to imagine a ways out of what seems to be a conflict of Poincare invariance with cosmological facts.

ZEO would explain the local non-conservation of average energies and other conserved quantum numbers in terms of the contributions of sub-CDs analogous to quantum fluctuations. Classical gravitation should have a thermodynamical description if this interpretation is correct. The average values of the quantum numbers assignable to a space-time sheet would depend on the size of CD and possibly also its location in M^4. If the temporal distance between the tips of CD is interpreted as a quantized variant of cosmic time, the non-conservation of energy-momentum defined in this manner follows. One can say that conservation laws hold only true in given scale defined by the largest CD involved.

Equivalence Principle at quantum level

The interpretation of EP at quantum level has developed slowly and the recent view is that it reduces to quantum classical correspondence meaning that the classical charges of Kähler action can be identified with eigen values of quantal charges associated with Kähler-Dirac action.

1. At quantum level I have proposed coset representations for the pair of super-symplectic algebras assignable to the light-like boundaries of CD and the Super Kac-Moody algebra assignable to the light-like 3-surfaces defining the orbits of partonic 2-surfaces as realization of EP. For coset representation the differences of super-conformal generators would annihilate the physical states so that one can argue that the corresponding four-momenta are identical. One could even say that one obtains coset representation for the "vibrational" parts of the super-conformal algebras in question. It is now clear that this idea does not work. Note however that coset representations occur naturally for the subalgebras of symplectic algebra and Super Kac-Moody algebra and are naturally induced by finite measurement resolution.

2. The most recent view (2014) about understanding how EP emerges in TGD is described in [K114] and relies heavily on superconformal invariance and a detailed realisation of ZEO at quantum level. In this approach EP corresponds to quantum classical correspondence (QCC): four-momentum identified as classical conserved Noether charge for space-time sheets associated with Käbler action is identical with quantal four-momentum assignable to the representations of super-symplectic and super Kac-Moody algebras as in string models and having a realisation in ZEO in terms of wave functions in the space of causal diamonds (CDs).

3. The latest realization is that the eigenvalues of quantal four-momentum can be identified as eigenvalues of the four-momentum operator assignable to the Kähler-Dirac equation. This realisation seems to be consistent with the p-adic mass calculations requiring that the super-conformal algebra acts in the tensor product of 5 tensor factors.

Equivalence Principle at classical level

How Einstein's equations and General Relativity in long length scales emerges from TGD has been a long-standing interpretational problem of TGD.

The first proposal making sense even when one does not assume ZEO is that vacuum extremals are only approximate representations of the physical situation and that small fluctuations around them give rise to an inertial four-momentum identifiable as gravitational four-momentum identifiable in terms of Einstein tensor. EP would hold true in the sense that the average gravitational four-momentum would be determined by the Einstein tensor assignable to the vacuum extremal. This interpretation does not however take into account the many-sheeted character of TGD spacetime and is therefore questionable.

The resolution of the problem came from the realization that GRT is only an effective theory obtained by endowing M^4 with effective metric.

1. The replacement of superposition of fields with superposition of their effects means replacing superposition of fields with the set-theoretic union of space-time surfaces. Particle experiences sum of the effects caused by the classical fields at the space-time sheets (see **Fig.** `http://tgdtheory.fi/appfigures/fieldsuperpose.jpg` or **Fig. ??** in the appendix of this book).

2. This is true also for the classical gravitational field defined by the deviation from flat Minkowski metric instandard M^4 coordinates for the space-time sheets. One can define effective metric as sum of M^4 metric and deviations. This effective metric would correspond to that of General Relativity. This resolves long standing issues relating to the interpretation of TGD.

3. Einstein's equations could hold true for the effective metric. They are motivated by the underlying Poincare invariance which cannot be realized as global conservation laws for the effective metric. The conjecture vanishing of divergence of Kähler energy momentum tensor can be seen as the microscopic justification for the claim that Einstein's equations hold true for the effective space-time.

4. The breaking of Poincare invariance could have interpretation as effective breaking in zero energy ontology (ZEO), in which various conserved charges are length dependent and defined separately for each causal diamond (CD).

One can of course consider the possibility that Einstein's equations generalize for preferred extremals of Kähbler action. This would actually represent at space-time level the notion of QCC rather than realise QCC interpreted as EP. The condition that the energy momentum tensor for Kähler action has vanishing covariant divergence would be satisfied in GRT if Einstein's equations with cosmological term hold true. This is the case also now but one can consider also more general solutions in which one has two cosmological constants which are not genuine constants anymore: it however seems that this option is not promising.

An interesting question is whether inertial-gravitational duality generalizes to the case of color gauge charges so that color gauge fluxes would correspond to "gravitational" color charges and the charges defined by the conserved currents associated with color isometries would define "inertial" color charges. Since the induced color fields are proportional to color Hamiltonians multiplied by Kähler form they vanish identically for vacuum extremals in accordance with "gravitational" color confinement.

Gravitational mass is necessarily accompanied by non-vanishing gauge charges

The experience from the study of the extremals of the Kähler action [K16] suggests that for non-vacuum extremals at astrophysical scales Kähler charge doesn't depend on the properties of the condensate and is apart from numerical constant equal to the gravitational mass of the system using Planck mass as unit:

$$Q_K = \epsilon_1 \frac{M_{gr}}{m_{proton}} \ . \quad (4.2.1)$$

The condition $\frac{\epsilon_1}{\sqrt{\alpha_K}} < 10^{-19}$ must hold true in astrophysical length scales since the long range gauge force implied by the Kähler charge must be weaker than gravitational interaction at astrophysical length scales. It is not clear whether the "anomalous" Kähler charge can correspond to a mere Z^0 gauge or em charge or more general combination of weak charges.

Also for the embedding of Schwartschild and Reissner-Nordström metrics as vacuum extremals non-vanishing gravitational mass implies that some electro-weak gauge charges are non-vanishing [K16]. For vacuum extremals with $sin^2(\theta_W) = 0$ em field indeed vanishes whereas Z^0 gauge field is non-vanishing.

If one assumes that the weak charges are screened completely in electro-weak length scale, the anomalous charge can be only electromagnetic if it corresponds to ordinary elementary particles. This however need not be consistent with field equations. Perhaps the most natural interpretation for the "anomalous" gauge charges is due to the elementary charges associated with dark matter. Since weak charges are expected to be screened in the p-adic length scale characterizing weak boson mass scale, the implication is that scaled down copies of weak bosons with arbitrarily small mass scales and arbitrarily long range of interaction are predicted. Also long ranged classical color gauge fields are unavoidable which forces to conclude that also a hierarchy of scaled down copies of gluons exists.

One can hope that photon and perhaps also Z^0 and color gauge charges in Cartan algebra could be quantized classically at elementary particle length scale ($p \leq M_{127}$, say) and electromagnetic gauge charge in all length scales apart from small renormalization effects. One of the reasons is that classical electromagnetic fields make an essential part in the description of, say, hydrogen atom.

The study of the extremals of Kähler action and of the embeddings of spherically symmetric metrics [K16, K114] shows that the embeddings are characterized by frequency type vacuum quantum numbers, which allow to fix these charges to pre-determined values. The minimization of Kähler action for a space-time surface containing a given 3-surface leads to the quantization of the vacuum parameters and hopefully to charge quantization. This motivates the hypothesis that the electromagnetic charges associated with the classical gauge fields of topologically condensed elementary particles are equal to their quantized counterparts. The discussion of dark matter leads to the conclusion that electro-weak and color gauge charges of dark matter can be non-vanishing [K38, K36].

4.2.4 Can One Regard # *Resp.* $\#_B$ Contacts As Particles*Resp.* String Like Objects?

#-contacts have obvious particle like aspects identifiable as either partons or parton pairs. $\#_B$ contacts in turn behave like string like objects. Using the terminology of M-theory, $\#_B$ contacts connecting the boundaries of space-time sheets could be also seen as string like objects connecting two branes. Again the ends holes at the ends of $\#_B$ contacts carry well defined gauge charges.

contacts as particles and $\#_B$ contacts as string like objects?

The fact that # contacts correspond to parton pairs raises the hope that it is possible to apply p-adic thermodynamics to calculate the masses of # contact and perhaps even the masses of the partons. If this the case, one has an order of magnitude estimate for the first order contribution to the mass of the parton as $m \sim 1/L(p_i)$, $i = 1, 2$. It can of course happen that the first order contribution vanishes: in this case an additional factor $1/\sqrt{p_i}$ appears in the estimate and makes the mass extremely small.

For # contacts connecting space-time sheets with opposite time orientations the vanishing of the net four-momentum requires $p_1 = p_2$. According to the number theoretic considerations below it is possible to assign several p-adic primes to a given space-time sheet and the largest among them, call it p_{max}, determines the p-adic mass scale. The milder condition is that p_{max} is same for the two space-time sheets.

There are some motivations for the working hypothesis that # contacts and the ends of $\#_B$ contacts feeding the gauge fluxes to the lower condensate levels or vice versa tend to be located near the boundaries of space-time sheets. For gauge charges which are not screened by vacuum charges (em and color charges) the embedding of the gauge fields created by the interior gauge charges becomes impossible near the boundaries and the only possible manner to satisfy boundary conditions is that gauge fluxes flow to the larger space-time sheet and space-time surface becomes a vacuum extremal of the Kähler action near the boundary.

For gauge bosons the density of boundary $\#_B$ contacts should be very small in length scales, where matter is essentially neutral. For gravitational $\#_B$ contacts the situation is different. One might well argue that there is some upper bound for the gravitational flux associated with single $\#$ or $\#_B$ contact (or equivalently the gravitational mass associated with causal horizon) given by Planck mass or CP_2 mass so that the number of gravitational contacts is proportional to the mass of the system.

The TGD based explanation for Podkletnov effect [H24] is based on the assumption that magnetically charged $\#$ contacts are carries of gravitational flux equal to Planck mass and predicts effect with correct order of magnitude. The model generalizes also to the case of $\#_B$ contacts. The lower bound for the gravitational flux quantum must be rather small: the mass $1/L(p)$ determined by the p-adic prime associated with the larger space-time sheet is a first guess for the unit of flux.

Could $\#$ and $\#_B$ contacts form Bose-Einstein condensates?

The description as $\#$ contact as a parton pair suggests that it is possible to assign to $\#$ contacts inertial mass, say of order $1/L(p)$, they should be describable using d'Alembert type equation for a scalar field. $\#$ contacts couple dynamically to the geometry of the space-time since the induced metric defines the d'Alembertian. There is a mass gap and hence $\#$ contacts could form a Bose-Einstein (BE) condensate to the ground state. If $\#$ contacts are located near the boundary of the space-time surface, the d'Alembert equation would be 3-dimensional. One can also ask whether $\#$ contacts define a particular form of dark matter having only gravitational interactions with the ordinary matter.

Also the probability amplitudes for the positions of the ends of $\#_B$ contacts located at the boundary of the space-time sheet could be described using an order parameter satisfying d'Alembert equation with some mass parameter and whether the notion of Bose-Einstein condensate makes sense also now. The model for atomic nucleus assigns to the ends of the $\#_B$ contact realized as a color magnetic flux tube quark and anti-quark with mass scale given by $k = 127$ (MeV scale) [K97].

This inspires the question whether $\#$ and $\#_B$ contacts could be essential for understanding bio-systems as macroscopic quantum systems [K23]. The BE condensate associated with the $\#$ contacts behaves in many respects like super conductor: for instance, the concept of Josephson junction generalizes. As a matter fact, it seems that $\#_B$ contacts, join along boundaries (JABs), or magnetic flux tubes could indeed be a key element of not only living matter but even nuclear matter and condensed matter in TGD Universe. Whether boundaries (and thus JABs) are allowed depends on whether boundary conditions for Kähler action allow space-like or light-like boundaries and in the simplest situation they do not seem to be allowed.

Decades after writing these lines it has become clear that Kähler action need not allow boundaries in the usual sense. They would be replaced with boundaries between space-time regions with Minkowskian and Euclidian signature and magnetic flux tubes carrying possibly monopole flux would replace join along boundaries contacts.

4.2.5 TGD Based Description Of External Fields

The description of a system in external field provides a nontrivial challenge for TGD since the system corresponds now to a p-adic space-time sheet k_1 condensed on background 3-surface $k_2 > k_1$. The problem is to understand how external fields penetrate into the smaller space-time sheet and also how the gauge fluxes inside the smaller space-time sheet flow to the external space-time sheet. One should also understand how the penetrating magnetic or electric field manages to preserve its value (if it does so). A good example is provided by the description of system, such as atom or nucleus, in external magnetic or electric field. There are several mechanisms of field penetration:

Induction mechanism

In the case of induction fields are mediated from level k_1 to levels $k_2 \neq k_1$. The external field at given level k_1 acts on $\#$ and $\#_B$ throats (both accompanied by a pair of partons) connecting levels

k_2 and k_1. The motion of # and $\#_B$ contacts, induced by the gauge and gravitational couplings of partons involved to classical gauge and gravitational fields, creates gauge currents serving as sources of classical gauge field at the space-time sheets involved. This mechanism involves "dark" partons not predicted by standard model.

A good example is provided by the rotation of charged # throats induced by a constant magnetic field, which in turn creates constant magnetic field inside a cylindrical condensate space-time sheet. A second example is the polarization of the charge density associated with the # throats in the external electric field, which in turn creates a constant electric field inside the smaller space-time sheet.

One can in principle formulate general field equations governing the penetration of a classical gauge field from a given condensate level to other levels. The simplified description is based on the introduction of series of fields associated with various condensate levels as analogs of H and B and D and E fields in the ordinary description of the external fields. The simplest assumption is that the fields are linearly related. A general conclusion is that due to the delicacies of the induced field concept, the fields on higher levels appear in the form of flux quanta and typically the field strengths at the higher condensate levels are stronger so that the penetration of field from lower levels to the higher ones means a decomposition into separate flux tubes.

The description of magnetization in terms of the effective field theory of Weiss introduces effective field H, which is un-physically strong: a possible explanation as a field consisting of flux quanta at higher condensate levels. A general order of magnitude estimate for field strength of magnetic flux quantum at condensate level k is as $1/L^2(k)$.

Penetration of magnetic fluxes via # contacts

At least magnetic gauge flux can flow from level p_1 to level p_2 via # contacts. These surfaces are of the form $X^2 \times D^1$, where X^2 is a closed 2-surface. The simplest topology for X^2 is that of sphere S^2. This leads to the first nontrivial result. If a nontrivial magnetic flux flows through the contact, it is quantized. The reason is that magnetic flux is necessarily over a closed surface.

The concept of induced gauge field implies that magnetic flux is nontrivial only if the surface X^2 is homologically nontrivial: CP_2 indeed allows homologically nontrivial sphere. Ordinary magnetic field can be decomposed into co-homologically trivial term plus a term proportional to Kähler form and the flux of ordinary magnetic field comes only from the part of the magnetic field proportional to the Kähler form and the magnetic flux is an integer multiple of some basic flux.

The proposed mechanism predicts that magnetic flux can change only in multiples of basic flux quantum. In super conductors this kind of behavior has been observed. Dipole magnetic fields can be transported via several # contacts: the minimum is one for ingoing and one for return flux so that magnetic dipoles are actual finite sized dipoles on the condensed surface. Also the transfer of magnetic dipole field of, say neutron inside nucleus, to lower condensate level leads to similar magnetic dipole structure on condensate level. For this mechanism the topological condensation of elementary particle, say charged lepton space-time sheet, would involve at least two # contacts and the magnetic moment is proportional to the distance between these contacts. The requirement that the magnetic dipole formed by the # contacts gives the magnetic moment of the particle gives an estimate for the distance d between # throats: by flux quantization the general order of magnitude is given by $d \sim \frac{\alpha_{em} 2\pi}{m}$.

Penetration of electric gauge fluxes via # contacts

For # contact for the opposite gauge charges of partons define the value of generalized gauge electric flux between the two space-time sheets. In this case it is also possible to interpret the partons as sources of the fields at the two space-time sheets. If the # contacts are near the boundary of the smaller space-time sheet the interpretation as a flow of gauge flux to a larger space-time sheet is perfectly sensible. The partons near the boundary can be also seen as generators of a gauge field compensating the gauge fluxes from interior.

The distance between partons can be much larger than p-adic cutoff length $L(k)$ and a proper spatial distribution guarantees homogeneity of the magnetic or electric field in the interior. The distances of the magnetic monopoles are however large in this kind of situation and it is an open problem whether this kind of mechanism is consistent with experimental facts.

An estimate for the electric gauge flux Q_{em} flowing through the # contact is obtained as $n \sim \frac{E}{QL(k)}$: $Q \sim EL^2(k)$, which is of same order of magnitude as electric gauge flux over surface of are $L^2(k)$. In magnetic case the estimate gives $Q_M \sim BL^2(k)$: the quantization of Q_M is consistent with homogeneity requirement only provided the condition $B > \frac{\Phi_0}{L^2(k)}$, where Φ_0 is elementary flux quantum, holds true. This means that flux quantization effects cannot be avoided in weak magnetic fields. The second consequence is that too weak magnetic field cannot penetrate at all to the condensed surface: this is certainly the case if the total magnetic flux is smaller than elementary flux quantum. A good example is provided by the penetration of magnetic field into cylindrical super conductor through the end of the cylinder. Unless the field is strong enough the penetrating magnetic field decomposes into vortex like flux tubes or does not penetrate at all.

The penetration of flux via dipoles formed by # contacts from level to a second level in the interior of condensed surface implies phenomena analogous to the generation of polarization (magnetization) in dielectric (magnetic) materials. The conventional description in terms of fields H, B, M and D, E, P has nice topological interpretation (which does not mean that the mechanism is actually at work in condensed matter length scales). Magnetization M (polarization P) can be regarded as the density of fictitious magnetic (electric) dipoles in the conventional theory: the proposed topological picture suggests that these quantities essentially as densities for # contact pairs. The densities of M and P are of opposite sign on the condensed surface and condensate. $B = H - M$ corresponds to the magnetic field at condensing surface level reduced by the density $-M$ of # contact dipoles in the interior. H denotes the external field at condensate level outside the condensing surface, M $(-M)$ is the magnetic field created by the # contact dipoles at condensate (condensed) level. Similar interpretation can be given for D, E, P fields. The penetrating field is homogenous only above length scales larger than the distance between # throats of dipoles: p-adic cutoff scale $L(k)$ gives natural upper bound for this distance: if this is the case and the density of the contacts is at least of order $n \sim \frac{1}{L^3(k)}$ the penetrating field can be said to be constant also inside the condensed surface.

In condensed matter systems the generation of ordinary polarization and magnetization fields might be related to the permanent # contacts of atomic surfaces with, say, $k = 139$ level. The field created by the neutral atom contains only dipole and higher multipoles components and therefore at least two # contacts per atom is necessary in gas phase, where flux tubes between atoms are absent. In the absence of external field these dipoles tend to have random directions. In external field # throats behave like opposite charges and their motion in external field generates dipole field. The expression of the polarization field is proportional to the density of these static dipole pairs in static limit. # contacts make possible the penetration of external field to atom, where it generates atomic transitions and leads to the emission of dipole type radiation field, which gives rise to the frequency dependent part of dielectric constant.

Penetration via $\#_B$ contacts

The field can also through $\#_B$ contacts through the boundary of the condensed surface or through the small holes in its interior. The quantization of electric charge quantization would reduce to the quantization of electric gauge flux in $\#_B$ contacts. If there are partons at the ends of contact they affect the gauge gauge flux.

The penetration via $\#_B$ contacts necessitates the existence of join along boundaries bonds starting from the boundary of the condensed system and ending to the boundary component of a hole in the background surface. The field flux flows simply along the 3-dimensional stripe $X^2 \times D^1$: since X^2 has boundary no flux quantization is necessary. This mechanism guarantees automatically the homogeneity of the penetrating field inside the condensed system.

An important application for the theory of external fields is provided by bio-systems in which the penetration of classical electromagnetic fields between different space-time sheets should play central role: what makes the situation so interesting is that the order parameter describing the # and $\#_B$ Bose-Einstein condensates carries also phase information besides the information about the strength of the normal component of the penetrating field.

4.2.6 Number Theoretical Considerations

Number theoretical considerations allow to develop more quantitative vision about the how p-adic length scale hypothesis relates to the ideas just described.

How to define the notion of elementary particle?

p-Adic length scale hierarchy forces to reconsider carefully also the notion of elementary particle. p-Adic mass calculations led to the idea that particle can be characterized uniquely by single p-adic prime characterizing its mass squared. It however turned out that the situation is probably not so simple.

The work with modelling dark matter suggests that particle could be characterized by a collection of p-adic primes to which one can assign weak, color, em, gravitational interactions, and possibly also other interactions. It would also seem that only the space-time sheets containing common primes in this collection can interact. This leads to the notions of relative and partial darkness. An entire hierarchy of weak and color physics such that weak bosons and gluons of given physics are characterized by a given p-adic prime p and also the fermions of this physics contain space-time sheet characterized by same p-adic prime, say M_{89} as in case of weak interactions. In this picture the decay widths of weak bosons do not pose limitations on the number of light particles if weak interactions for them are characterized by p-adic prime $p \neq M_{89}$. Same applies to color interactions.

The p-adic prime characterizing the mass of the particle would perhaps correspond to the largest p-adic prime associated with the particle. Graviton which corresponds to infinitely long ranged interactions, could correspond to the same p-adic prime or collection of them common to all particles. This might apply also to photons. Infinite range might mean that the flux tubes mediating these interactions can be arbitrarily long but their transversal sizes are characterized by the p-adic length scale in question.

The natural question is what this collection of p-adic primes characterizing particle means? The hint about the correct answer comes from the number theoretical vision, which suggests that at fundamental level the branching of boundary components to two or more components, completely analogous to the branching of line in Feynman diagram, defines vertices [K99, L43].

1. If space-time sheets correspond holographically to multi-p p-adic topology such that largest p determines the mass scale, the description of particle reactions in terms of branchings indeed makes sense. This picture allows also to understand the existence of different scaled up copies of QCD and weak physics. Multi-p p-adicity could number theoretically correspond to q-adic topology for $q = m/n$ a rational number consistent with p-adic topologies associated with prime factors of m and n ($1/p$-adic topology is homeomorphic with p-adic topology).

2. One could also imagine that different p-adic primes in the collection correspond to different space-time sheets condensed at a larger space-time sheet or boundary components of a given space-time sheet. If the boundary topologies for gauge bosons are completely mixed, as the model of hadrons forces to conclude, this picture is consistent with the topological explanation of the family replication phenomenon and the fact that only charged weak currents involve mixing of quark families. The problem is how to understand the existence of different copies of say QCD. The second difficult question is why the branching leads always to an emission of gauge boson characterized by a particular p-adic prime, say M_{89}, if this p-adic prime does not somehow characterize also the particle itself.

What effective p-adic topology really means?

The need to characterize elementary particle p-adically leads to the question what p-adic effective topology really means. p-Adic mass calculations leave actually a lot of room concerning the answer to this question.

1. The naïvest option is that each space-time sheet corresponds to single p-adic prime. A more general possibility is that the boundary components of space-time sheet correspond to different p-adic primes. This view is not favored by the view that each particle corresponds to

a collection of p-adic primes each characterizing one particular interaction that the particle in question participates.

2. A more abstract possibility is that a given space-time sheet or boundary component can correspond to several p-adic primes. Indeed, a power series in powers of given integer n gives rise to a well-defined power series with respect to all prime factors of n and effective multi-p-adicity could emerge at the level of field equations in this manner.

One could say that space-time sheet or boundary component corresponds to several p-adic primes through its effective p-adic topology in a hologram like manner. This option is the most flexible one as far as physical interpretation is considered. It is also supported by the number theoretical considerations predicting the value of gravitational coupling constant [K99].

An attractive hypothesis is that only space-time sheets characterized by integers n_i having common prime factors can be connected by join along boundaries bonds and can interact by particle exchanges and that each prime p in the decomposition corresponds to a particular interaction mediated by an elementary boson characterized by this prime.

The physics of quarks and hadrons provides an immediate test for this interpretation. The surprising and poorly understood conclusion from the p-adic mass calculations was that the p-adic primes characterizing light quarks u, d, s satisfy $k_q < 107$, where $k = 107$ characterizes hadronic space-time sheet [K66].

1. The interpretation of $k = 107$ space-time sheet as a hadronic space-time sheet implies that quarks topologically condense at this space-time sheet so that $k = 107$ cannot belong to the collection of primes characterizing quark.

2. Quark space-time sheets must satisfy $k_q < 107$ unless $\hbar$ is large for the hadronic space-time sheet so that one has $k_{eff} = 107+22 = 129$. This predicts two kinds of hadrons. Low energy hadrons consists of u, d, and s quarks with $k_q < 107$ so that hadronic space-time sheet must correspond to $k_{eff} = 129$ and large value of $\hbar$. One can speak of confined phase. This allows also $k = 127$ light variants of quarks appearing in the model of atomic nucleus [K97]. The hadrons consisting of c, t, b and the p-adically scaled up variants of u, d, s having $k_q > 107$, $\hbar$ has its ordinary value in accordance with the idea about asymptotic freedom and the view that the states in question correspond to short-lived resonances.

Do infinite primes code for q-adic effective space-time topologies?

Besides the hierarchy of space-time sheets, TGD predicts, or at least suggests, several hierarchies such as the hierarchy of infinite primes [K99], hierarchy of Jones inclusions [K118], hierarchy of dark matters with increasing values of $\hbar$ [K38, K36], the hierarchy of extensions of given p-adic number field, and the hierarchy of selves and quantum jumps with increasing duration with respect to geometric time. There are good reasons to expect that these hierarchies are closely related.

1. Some facts about infinite primes

The hierarchy of infinite primes can be interpreted in terms of an infinite hierarchy of second quantized super-symmetric arithmetic quantum field theories allowing a generalization to quaternionic or perhaps even octonionic context [K99]. Infinite primes, integers, and rationals have decomposition to primes of lower level.

Infinite prime has fermionic and bosonic parts having no common primes. Fermionic part is finite and corresponds to an integer containing and bosonic part is an integer multiplying the product of all primes with fermionic prime divided away. The infinite prime at the first level of hierarchy corresponds in a well defined sense a rational number $q = m/n$ defined by bosonic and fermionic integers m and n having no common prime factors.

2. Do infinite primes code for effective q-adic space-time topologies?

The most obvious question concerns the space-time interpretation of this rational number. Also the question arises about the possible relation with the integers characterizing space-time sheets having interpretation in terms of multi-p-adicity. On can assign to any rational number $q = m/n$ so called q-adic topology. This topology is not consistent with number field property like p-adic topologies. Hence the rational number q assignable to infinite prime could correspond to an effective q-adic topology.

If this interpretation is correct, arithmetic fermion and boson numbers could be coded into effective q-adic topology of the space-time sheets characterizing the non-determinism of Kähler action in the relevant length scale range. For instance, the power series of $q > 1$ in positive powers with integer coefficients in the range $[0, q)$ define q-adically converging series, which also converges with respect to the prime factors of m and can be regarded as a p-adic power series. The power series of q in negative powers define in similar converging series with respect to the prime factors of n.

I have proposed earlier that the integers defining infinite rationals and thus also the integers m and n characterizing finite rational could correspond at space-time level to particles with positive *resp.* negative time orientation with positive *resp.* negative energies. Phase conjugate laser beams would represent one example of negative energy states. With this interpretation super-symmetry exchanging the roles of m and n and thus the role of fermionic and bosonic lower level primes would correspond to a time reversal.

1. The first interpretation is that there is single q-adic space-time sheet and that positive and negative energy states correspond to primes associated with m and n respectively. Positive (negative) energy space-time sheets would thus correspond to p-adicity ($1/p$-adicity) for the field modes describing the states.

2. Second interpretation is that particle (in extremely general sense that entire universe can be regarded as a particle) corresponds to a pair of positive and negative energy space-time sheets labelled by m and n characterizing the p-adic topologies consistent with $m-$ and n-adicities. This looks natural since Universe has necessary vanishing net quantum numbers. Unless one allows the non-uniqueness due to $m/n = mr/nr$, positive and negative energy space-time sheets can be connected only by # contacts so that positive and negative energy space-time sheets cannot interact via the formation of $\#_B$ contacts and would be therefore dark matter with respect to each other.

   Positive energy particles and negative energy antiparticles would also have different mass scales. If the rate for the creation of # contacts and their CP conjugates are slightly different, say due to the presence of electric components of gauge fields, matter antimatter asymmetry could be generated primordially.

These interpretations generalize to higher levels of the hierarchy. There is a homomorphism from infinite rationals to finite rationals. One can assign to a product of infinite primes the product of the corresponding rationals at the lower level and to a sum of products of infinite primes the sum of the corresponding rationals at the lower level and continue the process until one ends up with a finite rational. Same applies to infinite rationals. The resulting rational $q = m/n$ is finite and defines q-adic effective topology, which is consistent with all the effective p-adic topologies corresponding to the primes appearing in factorizations of m and n. This homomorphism is of course not 1-1.

If this picture is correct, effective p-adic topologies would appear at all levels but would be dictated by the infinite-p p-adic topology which itself could refine infinite-P p-adic topology [K99] coding information too subtle to be caught by ordinary physical measurements.

Obviously, one could assign to each elementary particle infinite prime, integer, or even rational to this a rational number $q = m/n$. q would associate with the particle q-adic topology consistent with a collection of p-adic topologies corresponding to the prime factors of m and n and characterizing the interactions that the particle can participate directly. In a very precise sense particles would represent both infinite and finite numbers.

Under what conditions space-time sheets can be connected by $\#_B$ contact?

Assume that particles are characterized by a p-adic prime determining it mass scale plus p-adic primes characterizing the gauge bosons to which they couple and assume that $\#_B$ contacts mediate gauge interactions. The question is what kind of space-time sheets can be connected by $\#_B$ contacts.

1. The first working hypothesis that comes in mind is that the p-adic primes associated with the two space-time sheets connected by $\#_B$ contact must be identical. This would require that particle is many-sheeted structure with no other than gravitational interactions between various sheets. The problem of the multi-sheeted option is that the characterization of events like electron-positron annihilation to a weak boson looks rather clumsy.

2. If the notion of multi-p p-adicity is accepted, space-time sheets are characterized by integers and the largest prime dividing the integer might characterize the mass of the particle. In this case a common prime factor p for the integers characterizing the two space-time sheets could be enough for the possibility of $\#_B$ contact and this contact would be characterized by this prime. If no common prime factors exist, only $\#$ contacts could connect the space-time sheets. This option conforms with the number theoretical vision. This option would predict that the transition to large $\hbar$ phase occurs simultaneously for all interactions.

4.3 Model For Topologically Quantized Magnetic Field

4.3.1 Topological Field Quantization

Topological field quantization [K51] implies that various notions of quantum field theory have rather precise classical analogies. Topological field quantization provides the correspondence between the abstract Fock space description of elementary particles and the description of the elementary particles as concrete geometric objects detected in the laboratory. In standard quantum field theory this kind of correspondence is lacking since classical fields are regarded as a phenomenological concept only. Topological field quanta define regions of coherence for the classical fields and classical coherence is the prerequisite of the quantum coherence.

The energies and other classical charges of the topological field quanta are quantized by the criticality of the preferred extremals making classical space-time surfaces the counterparts of the Bohr orbits. Feynman diagrams become classical space-time surfaces with lines thickened to 4-manifolds. For instance, "massless extremals" representing topologically quantized classical radiation fields are the classical counterparts of gravitinos and photons. Topologically quantized non-radiative nearby fields give rise to various geometric structures such as magnetic and electric flux tubes.

The virtual particles of quantum field theory have also classical counterparts. In particular, the virtual particles of quantum field theory can have negative energies: this is true also for the TGD counterparts of the virtual particles. The fundamental difference between TGD and GRT is that in TGD the sign of energy depends on the time orientation of the space-time sheet: this is due to the fact that in TGD energy current is vector field rather than part of tensor field. Therefore space-time sheets with negative energies are possible. This could have quite dramatic technological consequences: consider only the possibility of generating energy from vacuum and classical signalling backwards in time along negative energy space-time sheets [K70, **?**]. Also bio-systems might have invented negative energy space-time sheets: in fact, so called "massless extremals" provide an ideal manner to generate coherent motions as recoil effects caused by the creation of negative energy massless extremals [K73, K72]. An interesting possibility is that quantum entanglement has the formation of the join along boundaries bonds/flux tubes as its geometric correlate.

The crucial question is of course "How to make this idea quantitative?". An attractive possibility is that topological field quanta identified as material or mind-like space-time sheets could be regarded as counterparts of oscillator operators of free fields in quantum field theory. This would mean that one could make order of magnitude estimates for the probabilities for the presence of various numbers of both material and mind-like space-time sheets using quantum field theoretical intuition. The coefficient of a particular state in the expansion of the creation operators of the outgoing interacting quantum fields in terms of the creation and annihilation operators of free quantum fields could provide an estimate for the probability that a particular configuration containing topological field quanta with positive and negative energies results in quantum jump between quantum histories. Since mind-like space-time sheets are correlates for virtual particles, this would also mean a deep connection between quantum field theory and cognition.

Topological field quanta could serve as templates for the formation of the bio-structures. Thus topologically quantized classical electromagnetic fields could be equally important for the functioning of the living systems as the structures formed by the visible bio-matter and the visible part of bio-system might represent only a dip of an ice berg.

Topological field quantization of magnetic field (see **Fig. 4.1**) means that given classical magnetic field is replaced with a bundle of flux tubes flowing along the field lines of classical magnetic field.

In TGD context magnetic flux tubes are really what they look, that is cylindrical 3-surfaces with *boundary* if one assumes that they do not carry monopole flux which is also possible by the topology of CP_2. Boundary can be present only if one adds to the Kähler action Chern-Simons term as boundary term. The boundary of the flux tube must by Maxwell equations contain rotating em or Z^0 charges creating the magnetic field in the interior (just like an induction coil creates an axial magnetic field inside it). The concept of topological field quantum generalizes also to the case of classical fields generated by wormholes.

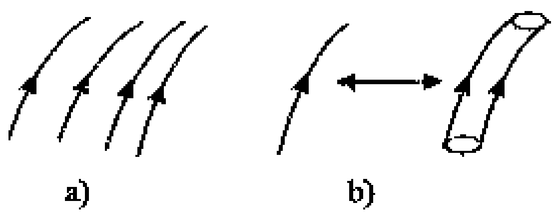

Figure 4.1: Topological field quantization for magnetic field replaces flux lines with flux tubes having outer boundary as 3-surfaces.

In case of wormhole super conductivity "charge carriers" are wormholes. Wormhole looking like charge $+Q$ on the "upper" sheet looks like charge $-Q$ on the "lower" sheet; when looked from the wider perspective (embedding space), wormhole behaves as a dipole with extremely small dipole strength. The currents associated with wormholes are of opposite sign on the two space-time sheets and magnetic flux tube consists of two fluxes: the flux on the "upper" space-time sheet and return flux on the "lower" space-time sheet (see **Fig. 4.2**). Closed wormhole flux tube can be visualized as two circles above each other and having Planck distance; the circles carry opposite magnetic fluxes. This visualization turns out to be useful later.

4.3.2 Mind Like Space-Time Sheets

The original formulation of quantum TGD led to the conclusion that there are two kinds of space-time sheets: material space-time sheets and mind-like space-time sheets so that one can say that Matter Mind duality is realized in geometrical sense: of course, Mind is understood in the sense of cognitive representations only. What one means with mind like space sheets is however not at all obvious.

1. The original proposal was that mind like space-time sheets have by definition a finite temporal extension. In zero energy ontology this holds true for all space-time sheets so that all space-time sheets would be mind-like. This could make perfect sense. For instance, the fermionic

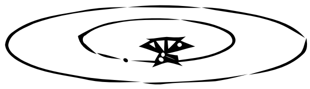

Figure 4.2: Artistic visualization of wormhole

part of zero energy state can be regarded as a logical rule $A \rightarrow B$ with the instances of A and B represented as positive and negative energy fermion states in Fock basis: the Fock basis for many-fermion states indeed defines a representation of Boolean logic.

2. Mind like space-time sheets could be also interpreted as p-adic space-time sheets responsible for cognition whereas real space-time sheets would be matter like in the sense that they define the space-time correlates of sensory experience. The intersection of p-adic and real worlds is along rational and common algebraic points of the embedding space and is discrete (note that this statement assumes the identification of preferred embedding space coordinates). p-Adic space-time sheets could serve as natural correlates of cognition and intentionality and their interaction with real space-time sheets could give rise to effective p-adic topology crucial for the interpretation of p-adic mass calculations. p-Adic space-time sheets have infinite size in real topology so that cognition and intentionality could not be localized in brain. Only the cognitive representations defined by the intersections of real and p-adic space-time sheets allow this localization.

3. p-Adic space-time sheets can be mapped to real space-time sheets via a generalization of the canonical identification map which is continuous and maps rationals m/n, $m, n < p^k$, $k > 0$. to rationals. The explicit form of the map is $m/n \rightarrow I_k(m)/I_k(n)$, with $I_k(m)$ defined as

$$x = \sum x_n p^{nk} \rightarrow \sum x_n p^{-nk} \quad .$$

This map could define the effective p-adic topology for real space-time sheets in finite measurement resolution reducing to discretized real topology above distances defined by the p-adic length scale corresponding to p^k. Below the resolution length scale the impossibility to well-order p-adic numbers would correspond to the impossibility to order space-time points by physical measurements. What makes this map attractive is that it commutes with the discrete counterparts of various space-time symmetries in the resolution defined by p^k and is also continuous.

4. In zero energy ontology two scales emerges naturally. The scale of causal diamond comes as an octave of CP_2 scale and corresponds to secondary p-adic length scale. The primary p-adic length scale characterizing elementary particles is essentially square root of this scale. In case of electron the latter scale is of order electron Compton length and the first one equals to.1 seconds defining the fundamental bio-rhythm. This suggests that MEs and magnetic flux tubes corresponding to secondary p-adic scale and having size of order CD size could be interpreted as mind-like space-time sheets. This interpretation will be adopted in the sequel.

4.3.3 Do Mind-Like Space-Time Sheets Perform Simple Mimicry?

Mind-like space-time sheets serve as quantum correlates of selves and are made possible by the classical non-determinism of the Kähler action and their defining property is finite temporal extension. mind-like space-time sheets are absolutely crucial for TGD inspired theory of consciousness since their presence is what makes possible conscious experiences with contents localized in a finite time interval, which characterized by the duration of the mind-like space-time sheet: without mind-like space-time sheets the contents of conscious experiences would not be temporally localized. Topological field quantization suggests the identification of the mind-like space-time sheets as classical counterparts of virtual particles, in particular, virtual photons. This suggests that some (not all) mind-like space-time sheets could be topological correlates of the internal (photon) lines of Feynman diagram and thus have naturally finite time duration.

Rather remarkably, TGD based notion of energy correlates the sign of energy with time orientation and allows mind-like space-time sheets to have also negative energy. Also wormhole-magnetic fields could be analogous to virtual particle pairs with vanishing total energy if the space-time sheets associated with the wormhole magnetic field have opposite time orientation. Mind-like space-time sheets provide cognitive representations and the simplest representation is direct mimicry. Hence one cannot exclude the possibility that wormhole magnetic fields form cognitive representations of the surrounding world in an extremely concrete manner: the magnetic field strength is the same as the field strength of the "real" magnetic field. This could hold true quite generally: pairs of space-time sheets with opposite time orientation could form cognitive representations of the external world such that the field strengths are same as those of the external world.

A concrete manner to achieve this mimicry is to glue mind-like space-time sheet pairs on the boundaries of the material space-time sheets by connecting the material space-time sheet by join along boundaries bond to the mind-like space-time sheet with a positive time orientation. This would mean that universe would be mimicking itself at classical level and in very concrete manner: note that this mimicry would resemble the emulation of Turing machines performed by Turing machines. In particular, the effect of em radiation on living matter at cyclotron frequencies of ions in Earth's magnetic field (or modulated by these frequencies) [J25] could be due to the fact that some ions "drop" (or rather, flow along join along boundaries bonds/flux tubes) to the space-time sheets of wormhole magnetic fields providing cognitive representation for Earth's magnetic field.

An interesting possibility is that cell membranes correspond to Z^0 wormhole magnetic fields glued to the boundaries of the cellular space-time sheets, or rather, are between and glued to the boundaries of cellular and extracellular space-time sheets characterized by same p-adic prime. The model for hearing and cognition is consistent with but does not require this assumption [K41, K43, K81].

This view reflects my thinking for more than decade ago. In particular, the notion of mind-like space-time sheet is based on the observation that determinism in its standard form fails and the idea that one can save determinism by allowing 3-surfaces consisting of union of disjoint space-time sheets with time-like separations. In zero energy ontology providing a more rigorous formulation for the generalized notion of classical determinism causal diamonds (CDs) defined as intersections of future and past directed light-cones play a key role. Space-time sheets connect the two light-like boundaries of CDs carrying opposite net quantum numbers. Mind-like space-time sheets could be identified as to space-time sheets associated with sub-CDs and would be analogous to radiative corrections in quantum field theory picture. One can of course argue that all space-time sheets are mind-like in this framework. For instance, the fermionic oscillator operators at the ends of space-time sheet provide a representation of Boolean algebra and zero energy states could be interpreted as Boolean statements of type A implies B.

One should not confuse mind-like space-time sheets with cognitive space-time sheets identified as p-adic counterparts of space-time sheets and having literally infinite size in real sense and a discrete intersection with real space-time sheets consisting of rational points and points in some algebraic extension of rationals.

4.3.4 Model For Wormhole Flux Tube As A Hollow Cylinder

In the absence of ordinary matter the electric part of gauge field is sourceless in the interior of the flux tube and one must assume the geometry of a *hollow cylinder* for the flux tube to avoid singularities. The wormhole charge densities on the inner and outer boundaries of the cylinder are of opposite sign and sourceless radial electric field is created in the interior of the cylinder. Rotational motion of the wormholes creates axial magnetic fluxes of opposite sign on the two space-time sheets. Clearly, the magnetic flux runs along the cylinder; goes to "lower" space-time sheet via magnetic wormhole, and returns along the "lower" space-time sheet. It is perhaps needless to add that hollow cylindrical structures are very frequent in bio-systems: representative examples are provided by microtubules and axons.

4.3.5 Wormhole Flux Tubes Need Not Be Closed In Ordinary Sense

The wormhole flux tube can apparently have an end unlike ordinary magnetic flux tube. At the end point the magnetic flux from the "upper" sheet flows to the "lower" sheet through *magnetic* wormhole, which looks like a magnetic monopole, when viewed from either sheet of 3-space. From embedding space perspective, one has extremely weak magnetic dipole, with monopoles located at Planck distance. Note that magnetic flux lines are closed as they should be.

The simplest expectation is that also wormhole flux tubes run along the closed field lines of the average classical magnetic field associated with the wormhole flux tube configuration. Wormhole flux tube structures can however form topologically much more complicated structures since one can construct also branched flux tubes by gluing two flux tubes together such that contact point contains magnetic wormhole.

4.3.6 Wormhole Flux Tubes Form A Macroscopic Quantum System

Since wormholes populate the boundaries of the flux tubes and since they form BE condensate, the entire exotic magnetic field configuration can be regarded as a macroscopic quantum system. Thus, according to TGD inspired theory of consciousness, flux tube configurations should be indeed controllable by quantum jumps and quantum mechanical free will becomes possible in the entire region covered by the exotic magnetic field configuration. One might even say, that wormhole condensate makes classical field a potential conscious being. This suggests that wormhole magnetic fields are crucial for the understanding the behavior of bio-systems as systems possessing free will.

The simplest possibility is that only the fluxes of the magnetic fluxes inside flux tubes are controlled by free will. As a consequence, psychokinetic effects on objects, which are wormhole super conductors, are in principle possible via a voluntary control of Meissner force (levitation). As found in [K51], magnetic fluxes associated with flux tubes are in general quantized so that control occurs in discrete steps.

4.3.7 The Interaction Of Coherent Light With Wormhole Flux Tubes

To understand Comorosan effect and phantom DNA effect to be considered in next section, one must construct a model for the interaction of wormholes with laser light. Needless to say, this interaction is fundamental for the TGD based description of bio-systems as macroscopic quantum systems.

1. Wormholes have coupling to the *difference* ΔA of the quantized gauge potentials describing photons (Planck size 3-surfaces) of topologically condensed coherent light on the two space-time sheets of the wormhole flux tube. This is due to the fact that wormhole behaves as a pair of two opposite charges on the two parallel space-time sheets connected by it.

2. The absorption of laser light can induce topology change for a closed wormhole flux tube. It is useful to visualize wormhole flux tubes as two one-dimensional closed circles above each other (within distance of Planck length). Clearly, the circles span in the initial situation *annulus*. The absorption of laser light can induce a pinching process in which the two circles are deformed so that they touch each other momentarily. At the moment of touching the circles are cut and the ends can recombine in two different ways to form a single circle. Either

the upper and lower ends of circle on the same side recombine to give single circle which spans *annulus with cut.* Or the upper and lower ends belonging to different sides recombine to form a circle with a twist of π, which spans a *twisted annulus*, known as Möbius strip, which is non-orientable, single-sided surface. The model for Comorosan and phantom DNA effects relies on the process *annulus* $\rightarrow$ *twisted annulus.*

4.3.8 Quantum Antenna Hypothesis And Wormholes

Quantum antenna hypothesis states that microtubules create a coherent state of photons (in particular bio-photons) and possibly also of gravitons. If the proposed model for the interaction between wormholes and coherent light is correct, then the presence of quantum coherent light in bio-system is necessary for the generation of currents in wormhole flux tube structures associated with DNA.

These currents correspond to phase gradients and the integer valued quantum numbers characterizing the phase increments around closed loops have been proposed to provide a coding of biological information and a model of memory [K23]. Although the model was constructed assuming that bio-system is ordinary super conductor, it works also for wormhole super conductor option. Note also, that the previous model fixes also the interaction between coherent photons and wormholes associated with the lipid layers of cell membrane, which is only one example of hollow cylinder like configurations frequent in bio-systems. An interesting possibility is that bio-system uses the twisted and untwisted configurations of closed flux tubes to store binary data.

Combining these ideas with the suggested identification for the quantum correlates of the sensory qualia, a definite picture of bio-system as a macroscopic quantum in which both wormholes and wormhole magnetic fields, coherent light electronic and neutrino Cooper pairs have essential roles, seems to emerge. [To be honest, this is actually quite an old discovery: the basic concepts of Hindu yoga are prana channels (wormhole flux tubes) and light (coherent photons)!].

4.3.9 Phantom DNA Effect, Comorosan Effect, DNA As A Conductor, ORMEs: Four Peculiar Effects With A Common Explanation

The concept of closed wormhole flux tube provides explanation for Comorosan effect and phantom DNA effect as also the conductivity of DNA [D19] described in [K21, K22]. The irradiation of bio-matter using visible laser light with certain preferred frequencies is crucial for *all* these effects. The interpretation is that irradiation transfers electron from one space-time sheet to another one (and creates automatically wormhole) and since the energy of electron is quantized, the preferred frequencies correspond to energy differences of electron on the two space-time sheets associated with the wormhole flux tube. This in turn provides support for the exotic atom concept providing explanation for the properties of ORMEs [H9].

4.4 Comorosan Effect, Phantom DNA Effect And Homeopathy

4.4.1 Comorosan Effect

The first model for Comorosan effect was based on super conductivity and the formation of Josephson junctions between interacting organic molecules assumed to contain closed super conducting current loops. The model reproduced the basic formula of Comorosan effect but *not all* aspects related to the interaction of laser light with organic molecule were understood. Wormhole super conductivity leads to much more precise model for this interaction and wormhole super conductivity is strongly favored over ordinary the super conductivity as an explanation of the effect.

The effect

Comorosan effect [I92, I33] demonstrates rather peculiar looking facts about the interaction of organic molecules with visible laser light at wavelength $\lambda = 546\ nm$. As a result of irradiation molecules seem to undergo a transition $S \rightarrow S^*$. S^* state has anomalously long lifetime and stability in solution. $S \to S^*$ 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 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 [I92, I33]. $t_m = m_E t_1$ 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 $t_a, t_b, ...$. 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.

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 must understand what this "very special" is, derive Comorosan formula from a physical model and find 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.

Model for the interaction of laser light with organic molecule

The model reproduces the basic formula of Comorosan effect but there were also some not so well understood aspects.

1. Effect occurs for *preferred frequencies* only. This can be understood if the process the interaction of laser light with wormhole flux tube involves transfer of electron from one condensate level to another one and thus a change of energy level. The transfer of electron leads to a creation of a wormhole.

2. 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. It seems that laser light just initiates some process which itself does not depend on the laser light.

3. The assumption that laser light stimulates the increase of a phase angle increment type variable defined over a loop, which is effectively cut in process, explains the preferred radiation times. What happens is that the phase increment increases linearly with time and for preferred radiation times the increase of phase angle is multiple of 2π so that the loop can close back again. The experience with super conductivity suggests the identification of the phase angle gradient as quantized momentum: the problem is to identify the carrier of this momentum.

An elegant explanation for these aspects of Comorosan effect results if one assumes that wormhole super conductivity is in question and that laser light induces a transformation of a closed wormhole tube spanning an *annulus* to that spanning a *twisted annulus*. Since the characteristic time scale is defined by the frequency of laser light, the process in question occurs very rapidly as compared to the time scale of order 5 seconds of the laser irradiaton. What is important is that the reverse process in which a twisted annulus transforms to an untwisted annulus cannot occur if the wormholes possess momentum k which is not multiple of $2\pi/L$ (by the quantization of momentum propagating in closed loop) and the wave length of laser length is large compared to the size of the loop.

The twisted annulus configuration leads to the acceleration of the wormholes and generation of longitudinal wormholes currents. If the initial, annulus type configuration of the flux tube contains constant wormhole charge density, then for the twisted annulus the charge density is of constant magnitude and of opposite sign on the different sides of each kink since the twist interchanges the "upper" and "lower" space-time sheets. Half of the structure corresponds to positive, and half of the structure to negative wormhole charge density (see **Fig. ??**).

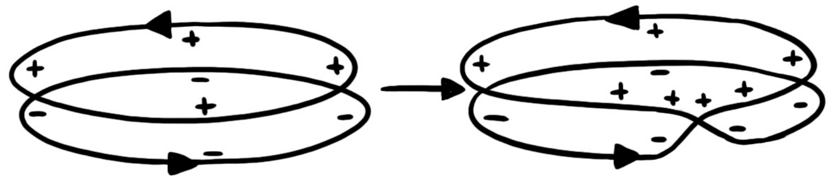

Figure 4.3: The interaction with laser light is assumed to induce the transformation of annulus configuration of wormhole flux tube to twisted annulus and creation of at least one wormhole pair with opposite charges. The members of wormhole pair go to separate kinks and create small longitudinal electric field.

One must assume that both kinks contain *additional wormhole charges of opposite sign* generated from vacuum, when the twisted annulus configuration is created in the interaction with the laser light. The creation of a twisted annulus is necessary in order to get a pair of opposite charges with large distance along the flux tube. These wormhole charges serve as sources of additional electric fields. Most of the electric flux flows in the radial direction of the flux tube but a small fraction $E_L = \epsilon E_{max}$ of the maximal flux $E_{max} = e/2S$, where S is the transverse area of the tube, is assumed to flow along the flux tube surface. E_L has constant magnitude and is of opposite sign on the "upper" and "lower" space-time sheets.

E_L accelerates the wormholes. The acceleration is of opposite sign at the opposite sides of the kinks and leads to the flow of the wormholes to the kink, where they must annihilate topologically. Newton's equation for the wormhole in external field gives wormhole momentum $k(t)$ as a function of time

$$\begin{aligned} \frac{dk}{dt} &= \epsilon 2eE \ , \\ E &= \frac{e}{2S} sign(x) \ . \\ sign(x) &= \begin{cases} -1, & x < 0 \ , \\ +1, & x > 0 \end{cases} \end{aligned} \tag{4.4.1}$$

Here $|x|$ measures the distance from the twist. The factor 2 in Coulomb force comes from the identical contributions of the two space-time sheets to the Coulomb force. The momentum of wormhole as function of time can also be obtained from the quantization condition

$$k - 2eA_L = 0 \ , \tag{4.4.2}$$

stating that wormhole order parameter is covariantly constant in the longitudinal direction. Since $A_L = E_L t$ holds true, one obtains same result as from Newton's equation.

Wormhole momentum increases linearly as a function of time since constant force is in question apart from the effect caused by the gradually decreasing density of wormholes caused by wormhole pair annihilation in kinks; this effect is however completely negligible since the time scale is so slow. In an excellent approximation the momentum gained by the wormholes in time t is

$$\begin{aligned} k(t) &= \epsilon\frac{e^2}{S}t = \frac{2\pi}{L}\frac{t}{t_0} \ , \\ t_0 &= \frac{1}{\alpha}\frac{1}{2\epsilon}\frac{S}{L} \ , \\ \alpha &= \frac{e^2}{4\pi} \ . \end{aligned} \tag{4.4.3}$$

Here t_0 is the time during which k achieves a value allowing the transitions back to the untwisted flux tube configuration. In agreement with the experimental data, the time scale t_0 is does not depend on the intensity of irradiation; t_0 should be of the order of 5 seconds. L should be considerably smaller than the wavelength of the visible light in case of Comorosan effect. For $\sqrt{S}$ and L of order 10^{-9} and 10^{-8} meters respectively one obtains the estimate $\epsilon \sim 10^{-16}$ so that the longitudinal fraction of electric gauge flux is extremely small.

For $t = t_n = nt_0$ wormholes have gained momentum $k = n2\pi/L$, for which the return to the ordinary closed untwisted flux tube configuration is possible. Laser light stimulates automatically transitions to the untwisted configuration. If laser light stimulation is not continued after t_n, a certain fraction of molecules is left to the closed untwisted loop state with wormhole momentum $k = n2\pi/L$. It is the presence of these loops carrying wormhole super current, which explains the change in the interactions of with organic molecules if interaction involves the formation of Josephson junctions between interacting molecules. If the stimulation is continued, also the closed untwisted loops suffer a re-transition to the twisted state and the momentum k continues to increase and the effect remains small. If stimulation ceases at such moment of time that k fails badly to satisfy the quantization condition the loops remain in twisted configuration and transitions to untwisted configuration are rare.

The explanation for Comorosan formula

It is assumed that organic molecules are wormhole super conductors containing closed wormhole flux tubes. The explanation as such does not differentiate between ordinary and wormhole super conductors.

If wormhole order parameter is proportional to a spatially non-constant phase factor then the flux tubes of the wormhole magnetic field carry longitudinal wormhole supra currents proportional to the gradient of the phase factor. The increment of the phase factor around any closed loop is $n2\pi$, n integer, and the momentum associated with the wormhole is proportional to n. These supra currents are created with the interaction of the wormhole flux tubes with laser light by a mechanism already considered.

Assume that enzyme contains a loop carrying wormhole supra current characterized by an enzyme specific integer m_E and created by the previously described interaction with the laser light. Assume that the substrate contains a similar loop, characterized by integer n_S. Assume further that in the enzyme-substrate interaction n_E Josephson junctions between the identical loops are formed and that the Josephson junctions are evenly spaced in Φ and there are either $n_E = 2s+1$ or $n_E = 2s$ junctions corresponding to ODDandEVEN receptors defined by Comorosan [I33]. Assume that the directions of the wormhole supra currents are same. The phase difference between the ends of the Josephson junction gives phase factor $exp(i(N_E - N_S)\Phi_n)$ to the current flowing through n: th junction and destructive interference in general occurs for the sum of Josephson currents. If the junctions are identical Josephson current is proportional to quantity U defined as a sum of phase factors

$$\begin{aligned} U &= \sum_{k=0,..,n_E} exp((m_E - n_S)\frac{i2\pi}{n_E}) \\ n_E &= 2s+1\ (ODD\ receptor) \\ n_E &= 2s\ (EVEN\ receptor) \end{aligned} \tag{4.4.4}$$

All phase factors are trivial and constructive interference occurs, when the condition

$$n_S = m_E + (k-1)n_E,\ k = 1,2,... \tag{4.4.5}$$

is satisfied. This is just the condition for for Comorosan effect to occur. Therefore, if the occurrence of constructive interference leads to enhanced enzymatic effect, that is "reading" of the substrate state in terminology of Comorosan, the model reproduces the experimental results of Comorosan for $k \leq 6$ and gives interpretation for m_E as angular momentum like quantum number associated with super current and n_E as the number of Josepshon junctions.

Note that Comorosan defines UP-type receptors as a receptor which read only ODD states with t_k odd multiple of t_1 [I33]. These correspond to odd value of m_E and even value of n_E. DOWN-type receptors read only DOWN-type states with t_k even multiple of t_1: these correspond to even values of m_E and n_E.UP-DOWN receptors correspond to odd values of m_E and n_E.

The model reproduces the basic experimental regularity observed by Comorosan with single exception. Comorosan has observed no effect for $t_{rad} > t_6$: according to the model the effect should be observed for all odd values of k and depend on $k_1 = k\ mod\ n_E$ only so that k and $k+n_E$ ought to lead to same effect. The problem looks difficult since t_6 is enzyme dependent parameter. The only manner to explain this observation seems to be following. Assume that substrate contains several loops L_i, one loop for each enzyme type E_i studied and that each loop is radiation detector in the sense already described. Assume that E_i-loop ceases to respond to irradiation, when the value of $\Delta\Phi$ exceeds the critical limit corresponding to $n_{cr}(E) = m_E + 5n_E$. One explanation for this behavior is that the supra current exceeds critical value and wormhole super conductivity is lost. The shorter the loop the smaller the critical value of $n_{cr}(E)$ is expected to be.

This model suggest that organic molecules are able to store memories into the integer valued vacuum quantum numbers associated with their supra current loops and that the interaction with coherent light, bio-photons perhaps, provides a mechanism of memory storage. The enzyme-substrate interactions in turn code this information to chemical form.

What is the origin of the 5 second time scale?

The time scale $\tau = 5$ seconds associated with the Comorosan effect has remained a teasing mystery for almost a decade. In particular, p-adic length scale hypothesis does not explain the time scale, and it does not correspond to any obvious time scale associated with magnetic transitions.

Only the model for quantum dark matter [K92] inspired by the fascinating findings that planetary orbits obey Bohr rules analogous to those for hydrogen atom but with a huge value of Planck constant equal to $\hbar_{gr} = GMm\hbar/v$, where v/c is a harmonic or sub-harmonic of $v_0/c = 4.8233 \times 10^{-4}$, led to a progress in the understanding of the time scale τ.

The idea about astro-quantal dark matter as a fundamental bio-controller by its gigantic value of Planck constant, inspires the guess that τ could relate to a quantal dark matter structure topologically condensed around a magnetic flux tube around a planetary Bohr orbit of radius R via the correspondence $\tau = R/c$. As observed by [E6], $n = 1$ orbit for $v_0 \rightarrow 3v_0$ corresponds in a good approximation to the solar radius $R_1 = AU/(9 \times 25) = R_S$ and thus to a time scale of 2.18 seconds. Since Earth's orbit corresponds to the principal quantum number $n = 5$, $n = 1$ orbit corresponds for $v_0 \rightarrow 2v_0$ to Bohr radius $R_1 = AU/4 \times 25 = (9/4)R_S$ and $\tau = AU/(4 \times 25) = 4.992$ seconds ($c = 1$): here $R = AU$ is the astronomical unit equal to the average distance of Earth from Sun. R corresponds approximately to the radius of solar core. The deviation from τ_C is only one per cent and of the same order of magnitude as the variation of the radius for the orbit due to orbital eccentricity $(a-b)/a = .0167$. [E3].

One could argue that $v_0 \rightarrow 2v_0$ is artificial trick unless one can assign it to the analog of $n = 1$ Bohr orbit with radius smaller than solar radius. v_0 would give for the orbit of $n = 1$ radius $R = AU/25$ roughly equal to and $\tau = 20$ s. $\tau = 5$ seconds could be interpreted in terms of 4:th harmonic in this case

An alternative explanation emerged with the discovery of dark matter hierarchy based on the scaled up values of M^4 and CP_2 Planck constants given as $\hbar(M^4) = n_a\hbar_0$ and $\hbar(CP_2) = n_a\hbar_0$, $n_i > 2$ [K40]. Typical quantum times and lengths, say Compton length and time, scale as n_a. The integers n_i have number theoretically preferred values which correspond to n-polygons constructible using only ruler and compass. These integers are given as $n = 2^k \prod_s F_s$, where each Fermat prime

F_s can appear only once in the product. F_s has the form $F_s = 2^{2^s} + 1$. The known Fermat primes are $3, 5, 17, 257$, and $2^{16} + 1$. If one scales the fundamental biological time scale $T_2(127 = .1$ s by $n_F = 3 \times 17$ one obtains the time scale $T = 5.1$ s.

4.4.2 Phantom DNA Effect

The phenomenon of phantom DNA [I46, I109] suggests that physical vacuum can have some additional structure with no obvious identification in the standard physics context. What is studied, is the scattering of the laser light on chamber, which is either empty or contains DNA. The autocorrelation function for scattered laser light is measured. This means in practise a linear array of detectors, which measure the number of scattered photons during certain time interval. There are three subsequent stages in the experiment.

1. Scattering chamber is empty. In this case autocorrelation function is random. The numbers of photons detected by various detectors are essentially random.

2. One adds the DNA in the chamber and finds that autocorrelation function is decaying exponential, which oscillates. This is due to the scattering of laser light on DNA.

3. One removes the DNA and instead of random autocorrelation finds that autocorrelation function exhibits exponential decay and oscillations also now! The numbers of photons detected are many orders of magnitude smaller but it is clear that something in the structure of vacuum, call it *phantom DNA*, serves as an effective scatterer of the laser light. For phantom DNA effect to occur it is essential that DNA in chamber is illuminated with laser light before its removal. The effect is long lasting, phantom DNA is detected even after period of months!

Is the mechanism explaining Comorosan effect behind phantom DNA effect?

The mechanism explaining Comorosan effect could explain also phantom DNA effect. Assume that the presence of DNA creates wormhole magnetic field, that is a net of wormhole flux tubes. This configuration is indeed vacuum configuration from the point of view of standard physics since the only "particles" are wormholes on the boundaries of the flux tubes. Laser light transforms closed untwisted flux tubes to twisted ones and accelerates wormholes so that they get net momentum.

When DNA is removed from the chamber, part of the wormhole magnetic field remains in chamber. If the chamber is now irradiated with laser light, the *wormhole supra currents* created in the irradiation of DNA interact with the laser light. Before the irradiation these currents vanish so that there is no effect. More quantitative argument goes as follows. Coupling is just the standard coupling of charged scalar field to the difference of topologically condensed coherent photon fields so that the interaction term is of the general form $\bar{\Psi}\Delta A\nabla\Psi$. In Fourier basis the couplings are of the form $e(k_i + k_f)A(k_i - k_f)$. If A is slowly varying, one has in good approximation $k_i = k_f$ for the allowed transitions, and transition matrix element is proportional to k. Thus the value of momentum k and thus coupling is appreciable *only* if DNA is irradiated before its removal.

The transfer of electron between the space-time sheets must be *crucial* for the process acceleration process. Otherwise, the irradiation of mere wormhole flux tube structure, "phantom DNA", would accelerate the wormholes creating supra currents and would eventually lead to stimulated emission.

Other explanations

With the development of the model for the bio-system as a macroscopic quantum system are also other possible explanations of the phantom DNA effect have emerged.

1. Perhaps the simplest explanation would be that a small fraction of DNA molecules drops to the magnetic flux tubes of Earth's magnetic field and scatters the coherent light.

2. The hypothesis that liquid crystal water blobs can mimic the electromagnetic body of the DNA molecule in the sense that some parts of the electromagnetic spectrum represented by MEs are more or less identical with that of DNA, could explain the phantom DNA effect in

terms of the liquid crystal blobs remaining when DNA is removed. The explanation would be same as for the effect of the homeopathic remedies. The explanation requires that LC water blobs are able to mimic the electromagnetic spectrum of DNA at visible frequencies. This is not at all obvious since water is transparent for visible light and thus does not have intense spectral lines in the visible frequency range.

4.4.3 Mind-Like Space-Time Sheets, Mimicry And Homeopathy

Homeopathy resembles phantom DNA effect in the sense that the repeated dilution of some drugs seems to give rise to a concentration of a "phantom drug" affecting the patient in some non-chemical manner. Standard science refuses to take homeopathy seriously. As often is the case with the paranormal phenomena, the refusal is based on very simple argument: standard science does not allow this kind of effect. TGD however framework allows room for homeopathy and homeopathy provides evidence for the notion of mind-like space-time sheet absolutely crucial for TGD based theory of consciousness as also for the general hypothesis that magnetic and Z^0 transition frequencies are quantum correlates of consciousness.

In TGD inspired theory of consciousness mind-like space-time sheets, which by definition have finite time duration, are geometric correlates of selves. TGD inspired theory of consciousness predicts that self hierarchy starts already from the elementary particle level and that the typical duration of self is given by the p-adic time scale $T_p = l \times L_p/c$, $l \simeq 10^4$ Planck lengths. For elementary particle selves the duration of wake-up time is of order Compton time and extremely short in human standards but extremely long when using the average duration of single quantum jump of order l/c as standard: elementary particle performs roughly $\sqrt{p}$ quantum jumps during its wake-up period and the values of p-adic prime are huge (electron has $p = 2^{127} - 1$).

If this scenario is correct, mind-like space-time sheets should accompany all forms of matter. Against this background it would not be too surprising that given drug would be characterized, not only by its chemistry, but also by the mind-like space-time sheets associated with its sub-selves. When the drug is dissolved into water, it can happen that mind-like space-time sheets associated with the drug lose their original owner and become (potential) sub-selves of the solvent. If this really happens, a concentration of mind-like space-time sheets associated with the "drug selves", remains into the solution, even when the drug is diluted to practically zero concentration. Water need not be a mere passive receiver of the mind-like space-time sheets of the drug but can also generate new mind-like space-time sheets mimicking the mind-like space-time sheets of drug. The effect of the drug on living organism involves self-organization and therefore also consciousness at some level. Thus is would not be surprising if "drug selves" were the effective component of some drugs and that the chemistry would only determine what "drug selves" and their effects are. This is indeed expected, since mind-like space-time sheets provide cognitive representations for the properties of the material space-time sheets associated with the drug.

One can imagine several options for how mind-like space-time sheets represent the relevant properties of drug. If cognitive space-time sheets perform direct mimicry of the material space-time sheets this scenario becomes even more plausible since mind-like space-time sheet and drug space-time sheets would not differ much in their electromagnetic properties. For instance, disease could involve the inability of some sub-selves of the organism to stay awake and self-organize: brisk new drug selves could simply replace these sleepish sub-selves and initiate the self-organization processes again! Note that direct mimicry might be involved also with the phantom DNA effect. The wormhole magnetic fields (or massless extremals) associated with DNA could mimic the classical fields associated with DNA molecule. TGD based concept of space-time allows in principle non-vanishing vacuum currents so that also the smoothed out charge distribution of DNA might be mimicked. If this indeed occurs, the interaction of the coherent light with DNA could resemble to some degree to its interaction with real DNA.

"Direct mimicry" understood as a generation of a copy about classical fields associated with the material space-time sheet (note that the sheet is 4-dimensional!) might be too strong a requirement. A more abstract mimicry is restricted on regeneration of dominating frequencies associated with the classical fields: this could be enough since it is resonance frequencies rather than amplitudes which are crucial for quantum control and coordination. The effects of ELF modulated em fields on living matter [J25] suggest that also amplitude modulation could be involved with the formation of the cognitive representations. mind-like space-time sheets associated with water could simply mimic the drug in frequency domain by reproducing the frequencies generated by the drug molecules or corresponding mind-like space-time sheets. That this might be the case is supported by the following arguments.

1. There are well documented effects related to the ability of water to absorb and transmit frequencies [J49] . The ability of water to absorb and transmit frequencies could rely on the generation of mind-like space-time sheets oscillating with the same frequency as stimulus. Water would form cognitive representation for the stimulus, mimic it.

2. The hypothesis that magnetic and Z^0 magnetic transitions frequencies are basic correlates of consciousness [K41] suggests that the effects of at least some drugs are quantum control effects and basically frequency mediated and that chemical effects are only secondary. If the effect of a drug indeed relies on its ability to generate an oscillation (say ELF em field) with some frequency and if this oscillation is generated by mind-like space-time sheets associated with water, then the mechanism of homeopathy could be understood.

Rather interestingly, subject persons allergic to a particular substance exposed to the substance and frequency at the same time develop after a short association period an allergic response to the frequency alone [J49]. A patient who has developed allergic response to certain frequency has also allergic response to water treated by the same frequency. Thus the water in human body together with central nervous system seems to have cognitive abilities, in particular ability to form associations. This suggests the possibility of associative medicine: the effect of drug is conditioned with frequency: in this manner the undesired side effects of the chemical drug could be circumvented.

4.4.4 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 [I44] (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 [L39]. 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 [?] [L39]. 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 $h = 6h_0$ [L26, L37] (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`).

1. **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 [I93, I33] 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 [K121] (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 [L34]. "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 [K121] I proposed that Josephson junctions are formed between reacting molecules in bio-catalysis. 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 [E6] for the value of gravitational Planck constant [K92, K71, K74, **?**] 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 m of 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 $\hbar_{eff} = \hbar_{gr}$ one has

$$r = \frac{\hbar_{gr}}{\hbar} = \frac{GM_D m}{c\beta_0} = 4.5 \times 10^{14} \times \frac{m}{m_p}\frac{y}{\beta_0} \quad .$$

   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

$$x = \frac{E}{eV} = 0.4 \times r \times \frac{f}{10^{14} Hz} \quad .$$

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

$$r = \frac{GM_D m_p}{\hbar\beta_0} \simeq .83 \times 10^{12} x \quad .$$

   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

$$x = \frac{E_J}{eV} = 0.4 \times .83 \times 10^{-2} \times \frac{m}{m_p} \times x\frac{f_J}{Hz} \quad , \quad E_J = ZeV \quad .$$

   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

$GM_Em_py/v_0 \simeq 10^{14}$ 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 [K15, K25] 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 [J23] 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 [L36] (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 [K81] 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 [K82, K37].

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}.

4.5 Subcellular Control And Wormhole Flux Tubes

4.5.1 Intracellular Bio-Control And Memory

Wormhole magnetic fields could provide a tool of quantum bio-control below cell length scales. For instance, cell nucleus could control from distance the motion of cell organelles using magnetic and Z^0 magnetic fields generated by wormholes. In [K23] it is suggested that the winding numbers associated with closed wormhole flux tubes, which actually correspond to quantized momenta for wormhole supra currents, might provide a memory, which is very stable against perturbations. It must be however emphasized that the TGD based model of long term memory does not require any memory storage since memories are essentially re-experienced episodes of geometric past. Wormhole supra currents, and the entire zoo of various supra-currents predicted by quantum TGD, might however form cognitive representations and an important brain function would be the construction of this kind of representations as caricatures of the conscious experience.

4.5.2 Coding Of Genetic Information To Topologically Quantized Fields?

The mechanisms behind ontogeny leading from single cell do an adult individual are poorly known. The wormhole flux tubes represent spatial extension of bio-system to a larger quantum system via magnetic fields so that long distance control via topologically quantized magnetic field becomes possible. As suggested in [K21, K22], either the flux tubes of ordinary or wormhole magnetic field could serve as templates of bio-structures: more specifically, wormhole flux tubes could provide topological representation for defects of various bio-super conductors.

Various bio-structures are expected to be surrounded by a characteristic flux tube network extending over a spatial region considerably larger than structure itself and bio-structure could control the fluxes inside the individual flux tubes. The field configuration would somehow control the ontogeny. By the previous considerations also the coherent photons created by microtubules and possibly other linear structures, could control the state of magnetic flux tubes. Note that also ordinary super conductivity with topologically quantized wormhole flux tubes representing defects might be involved. In this case the wormhole magnetic field cancels the penetrating field in the larger space-time sheet and recreates it in the smaller space-time sheet.

One can wonder how the genetic information is coded into extended spatial structures and to what extend wormholes flux tubes and various related structures represent something genuinely new. The p-adic hierarchy of space-time sheets certainly breaks naïve reductionistic philosophy so that the dynamics wormhole flux tubes and related structures is probably not completely determined by the genetic code. The idea about the flux tubes of magnetic field as templates for bio-structures does not support (or at least, does not require it) the idea about the coding of the magnetic structure to DNA and flux tube structure could be a result of self-organization process and topological field quantization. For instance, in case of DNA the structure of the topologically quantized wormhole magnetic field surrounding DNA (with quantized magnetic flux) can depend only on the general properties of the DNA sequence since only few topological quantum numbers are involved and it indeed seems that these quantum numbers are determined by the dynamics at larger length scales in accordance with Slaving Principle. On the other hand, the structure of the wormhole magnetic fields in length scales shorter than DNA could be determined completely by the structure of DNA sequence.

4.5.3 Are Magnetic And Wormhole Magnetic Fields Involved With The Control Of Gene Expression?

The development of organism is a complicated self-organization process during which gene expression is controlled by the feedback from long length scales. The mechanism of this "biofeedback" is poorly understood. It is not even known whether it is really chemical. In fact, it is known that besides the chemical transcription factors (proteins) controlling gene expression, there are non-chemical transcription factors called silencers and enhancers, whose action mechanism is not known [K55] , [I30]. Magnetic and wormhole magnetic fields could indeed be involved with the control of gene expression performed by growing organism using Josephson currents.

1. As suggested in [K73, K72], magnetic and perhaps also wormhole magnetic fields could be involved with the gene expression via Josephson currents and make possible biological alarm clocks "waking-up" gene self and initiating gene expression. Complicated circuits, involving pattern recognizers, comparison circuits and novelty detectors could serve as building bricks of logical circuits conditioning the gene expression to begin only when certain conditions are satisfied.

2. The realization of the alarm clock would be following. Ions and electrons form in the magnetic fields or wormhole magnetic fields bound states characterized by cyclotron frequencies. When the potential difference between the space-time sheets representing two weakly couple super conductors connected by the join boundaries bonds representing Josephson junctions equals to a magnetic transition frequency of a charge carrier in either superconductor, quantum jumps occur and "wakes-up" the "clock self" and initiate thus self-organization process.

3. One can imagine that the genetic alarm clock is formed by Josephson junction formed by one of the many space-time sheets associated with the many-sheeted DNA and the space-time sheet of the growing organ [K55]. The size of the space-time sheet correlates with the vacuum frequency ω_1 of the space-time sheet (there are two frequency type vacuum quantum numbers denoted by ω_1 and ω_2 [L2] and a natural assumption is that the difference of the frequencies ω_1 associated with the gene space-time sheet and organ's space-time sheet corresponds to the electromagnetic potential difference over Josephson junction: $\Delta\omega_1 = ZeV$. When this difference equals to the energy difference for the states localized in either super conductor, the superconductor "wake up". Thus a precise timing for the wake-up results and the initiation of the gene expression correlates in a precise manner with the size of the organ. This is something highly nontrivial: chemical transcription factors are concentrations and it is very difficult to imagine how concentrations, which carry purely local information, could code precise information about the size of the organ and even use it to control purposes.

4. If the states are cyclotron states confined in (wormhole) magnetic fields, the energy difference is in general case difference for multiples of the corresponding cyclotron frequencies. This flow of charge would eventually lead to the "wake-up" of the gene and initiate the self-organization process leading to gene expression.

4.5.4 Wormhole Flux Tubes As Templates Of Bio-Structures

One aspect of control of ontogeny is that part of a flux tube structure could serve as a template in the sense that bio-matter gathers around flux tubes during ontogeny. According the considerations of [K21, K22], magnetic or wormhole magnetic fields could provide general representation for the defects of super conductors. Microtubules, axons and very many other basic bio-structures are indeed *hollow* cylinders identifiable as defects of super conductors of type II (electronic super conductors). It is also known that macroscopic cylindrical bio-structures such as legs are characterized by winding numbers (for rather peculiar consequences, see [A3]): this suggests that wormhole condensates associated with the boundaries of bio-sub-structures of all sizes play important role in bio-control. The stripe like structures (cell membranes, epithelial sheets, larger bi-layered structures of brain) could in turn correspond to defects of super conductors of type I (neutrino super conductors).

Ordinary atom could topologically condense on the interior of the flux tubes and topological condensation could become stable if one or more valence electrons is dropped on the "lower" space-time sheet of the flux tube. The resulting atom would be "exotic atom" with chemical properties those of atom having Z smaller by one unit (electronic alchemy!). As a matter of fact, the potential importance of the wormhole concept became clear from the attempt to explain the peculiar properties of so called ORMEs [H9] in terms of the concept of exotic atom [K21, K22].

The formation of exotic atoms might have been the basic step from the ordinary chemical evolution to bio-evolution. The process would be amplified by the presence of wormholes on the magnetic flux tube just like the formation of BE condensate is catalyzed by the presence of already existing seed of BE condensate (condensation probability is proportional to N^2, where N is the number of bosons in ground state). The possibility that Na, K, Ca ions in cell could be really exotic atoms with s wave valence electron(s) dropped on the lower space-time sheet, is not excluded.

4.6 TGD Inspired Models For Psychokinesis

The reality of psychokinesis (PK) as of also other psi phenomena is subject of a continuous debate and it seems that opinions are not always based on rational arguments. I am personally neither believer nor non-believer of psi phenomena but regard it as important (and also entertaining) to try to find rational testable models for psi rather than ridiculing or mystifying it. Indeed, in the following a TGD inspired model of psychokinesis is considered.

The basic philosophy of the model is following. PK is not just some isolated exotic phenomenon but only a special case of the voluntary control of bodily motions, which we all routinely perform. The only difference is that the range of voluntary control extends over the boundaries of the body in case of PK. This leads to an important conclusion: PK phenomena must involve classical long range fields, which give for bio-systems spatial extension larger than what is visible (that is hands with which to grasp on external object!). According to TGD inspired theory of consciousness, cell and even DNA can be conscious and perform choices. Thus the model should also provide understanding about small scale bio-control such as the (voluntary!) control of the motion of cell organelles performed by cell nucleus. A related problem is how genetic code is transformed into spatial structures during ontogeny, and the idea that each DNA sequence corresponds to a characteristic classical field configuration, is attractive. Thus the model in question is not meant to be an ad hoc solution of a particular problem called PK but a general solution of several basic problems in biology.

4.6.1 Wormhole Magnetic Fields And Psychokinesis

The model for psychokinesis is fixed to rather high degree by the following arguments.

PK as a special case of voluntary action

Our subjective experience tells that our bodily motions are controlled by our free will. Only the fact, that we are so familiar with this PK in the scale of our own body, makes us believe that nothing peculiar is involved. This suggests that PK-able persons differ from ordinary people in that they can perform PK also in length scales larger than their own body. PK is probably possible and probably occurs also below cell length scales, say in the control of motions of cellular organelles by nucleus. Also DNA and microtubules could perform PK. The only logical conclusion is that PK, as well as voluntary control of motion, involves long range classical fields effectively giving for PK-able system hands with which to grasp on the external object.

Quantum entanglement and PK

Quantum entanglement plays basic role in TGD inspired theory of consciousness and this is especially so for TGD inspired model of psi phenomena such as telepathy [K83]. Therefore it is assumed that PK mechanism involves quantum entanglement of some part of brain B with some part S of body such that S has ability to generate some classical field, which affects the material object. The field depends sensitively on quantum state of S so that the control becomes possible via B-S entanglement and quantum jumps reducing the entanglement. The most promising classical fields are magnetic fields (ordinary or Z^0-).

p-Adic considerations might exclude the possibility of PK in many cases. Suppose that, as strongly suggested by QFT limit of TGD, the space-time sheets indeed have effective p-adic topology characterized by p-adic prime. The tensor product for p-adic state spaces with different p-adic primes p_1 and p_2 gives rise to R_p valued state space, where p is the p-adic prime associated with the entire system. There are some reasons to believe that $p_1 \neq p_2$ quantum entanglement is rare phenomenon: if true this implies the decomposition of the space-time into separate space-time sheets labelled by primes and behaving more or less classically with respect to each other: this is certainly in accordance with the everyday intuition. An immediate consequence is that subsystems of brain can get quantum entangled mostly with subsystems having same p. Furthermore, the space-time sheet for the object of PK should be such that magnetic field created by PK is on the space-time sheet at which it the object has suffered topological condensation.

Bio-systems and classical Z^0 fields

Bio-matter must be in special position as far as PK is considered and thus cell length scale should be somehow in special role in the possible explanation of PK. Indeed, TGD predicts that the prime $p \simeq 2^{169}$ corresponds to the primary condensation level of neutrinos (on basis of data from latest neutrino mass experiments [K56]. The corresponding p-adic length scale corresponds to cell size. This p-adic condensation level is also the p-adic condensation level at which nuclei must feed their Z^0 charges, where they in turn are screened by neutrinos (this requirement is necessitated by the stability of condensed matter against *classical* long range Z^0 force). In this manner one also avoids the large parity breaking effects caused by classical Z^0 fields, if present in atomic length scales.

Thus *neutrinos* and *classical* Z^0 force correspond to the new TGD-based physics emerging at cell length scale. TGD neutrinos are predicted to be super-conducting and classical Z^0 magnetic fields break the super conductivity: an attractive possibility is that cell membranes and endoplasma membranes correspond to the defects in the resulting superconductor of type I. The explanation of chirality selection [K38] in terms of Z^0 magnetic fields and neutrinos and of tritium beta decay anomaly [K97] provide strong support for this picture. The additional important piece of new physics important for bio-systems is related to *wormhole contacts*. For instance, wormhole contacts are created when electrons of ordinary atom drops from atomic space-time sheet to a larger space-time sheet parallel to it. This process leads to so called exotic atom [K21, K22] explaining the peculiar properties of so called ORMEs [H9]. In fact, the dropping of electron on larger space-time sheet might have been a (perhaps even the!) crucial step in transforming chemical evolution to bio-evolution. Also the penetration of classical electric and magnetic fields from a space-time sheet to another one requires the presence of charged wormholes and classical em fields are known to be very important in bio-systems.

In many-sheeted space-time particles topologically condense at all space-time sheets having projection to given region of space-time so that this option makes sense only near the boundaries of space-time sheet of a given system. Also p-adic phase transition increasing the size of the space-time sheet could take place and the liberated energy would correspond to the reduction of zero point kinetic energy. Particles could be transferred from a portion of magnetic flux tube portion to another one with different value of magnetic field and possibly also of Planck constant h_{eff} so that cyclotron energy would be liberated.

Magnetic levitation as a basic mechanism of PK

The simplest possibility is PK effect is based on magnetic levitation. Both classical magnetic and Z^0 magnetic fields can give rise to the effect. This requires that all objects which can be moved by PK, must be diamagnetic and repel from their interior external magnetic fields by generating currents on their boundaries. If they behave like superconductors (in some sense) this is indeed the case.

Wormholes feed the gauge flux from a smaller p-adic space time sheet to a larger one and the throats of the wormhole look like classical charges of opposite sign coupling to the difference of classical fields associated with the two space-time sheets. When looked from embedding space context, they can be regarded as extremely weak dipoles and their coupling to vapor phase photons is extremely weak, which explains why they have not been observed via radiation. Wormhole Bose-Einstein condensates are a purely TGD-based phenomenon. Z^0 wormholes have classical $Z0$ interaction with atomic nuclei screened by neutrinos and this in turn couples them to phonons and electromagnetic interactions indirectly. If Z^0 are in thermal equilibrium with ordinary matter then wormhole Bose-Einstein condensates are possible in the length scales below $L = 1/T$ (T is temperature, in room temperature L is about $10^{-5} - 10^{-4}$ meters).

Wormhole BE-condensate behaves in many respects like super conductor. Thus wormhole superconductivity is a possible candidate for a mechanism behind PK. What is required is that the density of wormholes on the boundary of the object is high enough so that surface currents can cancel external magnetic field and magnetic levitation becomes possible. Charged wormholes provide also a mechanism of electronic bio-super conductivity and also this might be involved in PK as it possibly appears in bio-control.

Topological field quantization could make possible precise quantum control of magnetic fields

Bio-system must has an ability to create and control in precise manner magnetic fields. The only manner to achieve this is to construct magnetic field from magnetic flux tubes with *quantized magnetic fluxes*. Actually, the decomposition into flux tubes with quantized magnetic fluxes occurs *automatically* for any magnetic field in TGD [K51]. This is due to the induced gauge field concept: the embedding of classical gauge field as induced gauge field in general fails outside some region and 3-surface with boundary is generated (in [K51] these regions were christened as topological field quanta). Since wormholes form a Bose-Einstein condensate on the boundaries of flux tubes, topological field quantization actually makes the classical magnetic field quantum object and potential conscious being if TGD inspired theory of consciousness is correct! Control of the magnetic field occurs via the control of the order parameter describing the state of the wormhole condensate.

PK mechanism could be at work below cell length scale for ordinary magnetic fields and it is tempting to speculate that this kind of PK is one of the basic mechanisms of intracellular control. For instance, cell nucleus could control from distance the motion of cell organelles using magnetic and Z^0 magnetic fields generated by wormholes. Also microtubules and perhaps even DNA could apply PK mechanism for control purposes. In longer length scales, much above the cell length scale, Z^0 type wormhole magnetic fields might be important.

Order of magnitude estimates

One can imagine several mechanisms for the penetration of the magnetic and wormhole magnetic fields. If the size of the object is small as compared to the thickness of the flux tube, the wormhole magnetic field at either sheet can penetrate (or try to penetrate in present case!) to the space-time sheet of an object topologically condensed at the space-time sheet of the flux tube. When the size of the object is larger than the thickness of the magnetic flux tube, situation is more complicated: a similar microscopic mechanism could however be at work also in this case since the object contains hierarchy of smaller space-time sheets topologically condensed on it. The following discussion neglects these complications and treats the (wormhole) magnetic field as ordinary classical fields: intuitively the idealization of the flux tube structure with ordinary classical magnetic field seems natural.

The energy for creating and changing magnetic or wormhole magnetic fields must come from the metabolism. Dissipation effects are expected to be small since wormholes behave as a super conductor. Super conductivity (perfect diagmagnetism) is not necessary, also nonperfect diamagnets can levitate. In case of super conducting object the strength of the magnetic field must be smaller than the critical field destroying the super conductivity; this condition is a crucial limitation for PK based on super conductivity.

A rough order of magnitude estimate for the needed magnetic field strengths is obtained in the following manner. Meissner force is the gradient of the magnetic field energy regarded as a function of the position of the object located in the field. For simplicity, assume that (wormhole) magnetic field depends linearly on the coordinate z in the direction of gravitational field

$$B = B_0(1+\frac{z}{h}) \ , \tag{4.6.1}$$

where h is the characteristic scale of variation for the wormhole magnetic field.

The Meissner force experienced by an object having size much smaller than scale h, so that the magnetic field is essentially constant in the volume of the object, is from a rough order of magnitude estimate

$$\begin{aligned} F &\sim -\frac{dE_{magn}}{dz} \ , \\ E_{magn}(z) &\simeq \frac{1}{2}B^2V = \frac{B_0^2V}{2}(1+\frac{z}{h})^2 \ , \end{aligned} \tag{4.6.2}$$

where E_{magn} is the magnetic field energy contained in the volume V of the object. For the lifting of an object with mass m in the gravitational field, this force must have a magnitude larger than the gravitational force $F = mg$, where g is gravitational acceleration. This gives an order of magnitude estimate for the minimum magnetic field B_0 making the lifting of the object possible:

$$B_0 \sim \sqrt{\rho g h} \ , \tag{4.6.3}$$

where ρ is the density of the object. Note that in the approximation that magnetic field is essentially constant in the volume of the object, the estimate does not depend on the size or form of the object. More generally, the gradient of B is roughly the gravitational force divided by the average magnetic field B_0: $\frac{dB}{dz} \sim \frac{\rho g}{B_0}$.

An order of magnitude estimate is obtained by putting $\rho \sim 10^3\ kg/m^3$ (density of water roughly) and $h \sim 10^{-2}\ meters$ (object could be a sheet considerably thinner than one centimeter). In this case magnetic field B_0 of order $10^{-5}\ Tesla$ is needed.

Consider first ordinary super conductivity and ordinary magnetic fields (assuming object to be super conductor). Hudson claims that the critical magnetic fields for ORME superconductivity are of the order of Earth's magnetic field, about $10^{-7}\ Tesla$. The claim concerns ordinary magnetic field, not wormhole magnetic fields, and thus electronic superconductivity should be in question. If the claim gives general order of magnitude then the needed magnetic field would destroy the electronic super conductivity. By reducing the thickness of the object to the cell length scale of order $10^{-6}\ meters$, one finds that the needed magnetic field is of order $10^{-7}\ Tesla$ so that the effect might be possible below cell length scales and cell nucleus might control the motion of cell organelles by PK based on the ordinary magnetic fields and electronic super conductivity.

Second case corresponds to wormhole super conductivity (object must be wormhole super conductor). Since wormhole magnetic fields are new physics, one can make only order of magnitude guesses. "Ordinary" wormhole magnetic fields can exist in arbitrarily short p-adic length scales and there is no obvious upper bound for the critical wormhole magnetic field in this case. Since Z^0 classical fields appear only in the p-adic length scales not smaller than the cell length scale, p-adic length scale hypothesis suggests that the critical wormhole magnetic field is in this case *at most* of the order $1/L(cell)^2$ in units ($\hbar = c = 1$). This gives $B_0 \leq 10^{-4}\ Tesla$. This would be enough in the previous example with a sheet like object having the density of water and thickness below one centimeter. Note that thin sheets are ideal objects for the experimental verification of the effect.

4.6.2 Alternative Models Of Psychokinesis

The manner TGD solves the energy problem of GRT is simple: energy momentum tensor is replaced by a collection of vector fields so that the energy defined as an integral over 3-space is coordinate independent scalar quantity. Vector field nature however implies that the sign of the energy depends on the time orientation of the space-time sheet and one can quite well consider the possibility that the time orientation of the space-time sheet is not always same as the natural time orientation of the future light-cone. This would make possible negative energies and "buy now, pay later" type mechanism of energy production by the generation of negative energy space-time sheets of possibly finite time duration. One can even consider the possibility that entire universe is generated from vacuum and has vanishing total quantum numbers.

In [K114] this mechanism is discussed as an explanation for certain peculiar looking claims about energy production occurring with efficiency larger than one. (the N-machine of DePalma [H7] and the space energy generator of [H3]). The model also explains why the rotation of a system consisting of a conductor disk rigidly attached to a cylindrical magnet generates potential difference between the axis and rim of the conducting disk. This effect, observed already by Faraday, has no satisfactory explanation in ordinary electrodynamics. In TGD framework the explanation is simple: the mere rotation of the 3-surface generates the radial electric field automatically. The divergence of the electric field associated with the Faraday disk is non-vanishing and gives rise to vacuum charge density and this in turn implies the necessity of second space-time sheet with opposite charge density and possibly opposite time orientation.

One can consider the possibility that "mind-like" space-time sheets could have negative time orientation so that pairs of space-time sheets with opposite time orientations could be the basic characteristic of living matter. In fact, only this option could make possible the realization of Boolean mind relying on electron positron pairs. Note that also wormhole magnetic fields could correspond to pairs of space-time sheets having opposite time orientation. If this picture is correct, psychokinetic effects could occur spontaneously in living systems when mind-like space-time sheets with negative time orientation are generated and material space-time sheet receives compensating positive energy. This mechanism would make possible “poltergeist” effects involving generation of kinetic energy from “nowhere” and would make possible to affect the physical world by mere thought! There also legends about the magic feats of the trained yogis. Sceptics have of course strong opinions concerning these stories: I would be happy if I could share with the sceptics their access to deeper knowledge making life so simple. I do no even know whether we might be affecting everydaily that part of the physical world which we identify as our physical body by this mechanism!

TGD suggest also a third mechanism of PK. Space-time sheets form a hierarchy. Our space-time sheet is usually glued to the space-time sheet of Earth so that we feel the gravitational force of Earth. One could however consider the possibility that “our” space-time sheet could in some manner get glued to a larger space-time sheet at which Earth’s gravitational field is not felt appreciably. This would make possible levitation. This kind of effect would also make the apparent fusion of solid bodies and an effect that might be called “Houdini effect”. The occurrence of this effect in atomic length scales makes possible to bypass Coulomb walls and has been suggested as a mechanism of cold fusion in [K97].

4.6.3 Experimental Tests

The basic concept is topological field quantization implying the decomposition of magnetic field to flux tubes. This indeed occurs in super conductors. Actually, it might be that this phenomenon can be demonstrated using just child’s toy magnet! The ferrite powder on table indeed concentrates on lines in the vicinity of magnet. I do not know whether this phenomenon has a more mundane explanation or is it really a direct manifestation of topological field quantization.

The simplest experimental proof for the wormhole flux tube idea is to make them visible! One could achieve the situation in which atoms are condensed on wormhole flux tubes and form exotic atoms so that also electronic alchemy occurs: one can hardly imagine more dramatic proof of the concept! A second possibility is the interaction of laser light with wormhole flux tubes if the proposed explanation of phantom DNA effect is correct. The recent progress in understanding of high T_c superconductivity [K21, K22] gives indeed very strong indirect support for the notion of wormhole contact as parton-antiparton pair as well as for the notion of dark matter as large $\hbar$ phase of ordinary matter.

There are two possible realizations for PK in the proposed model. Either in terms of ordinary topologically quantized magnetic field and super conductivity or in terms of wormhole super conductivity and corresponding magnetic fields, which always appear on *two* space-time sheets simultaneously and thus forming twin structures. The essential requirement is that magnetic field is on the space-time sheet at which the object has suffered topological condensation. Also the restrictions from p-adic quantum entanglement and from many-sheetedness of the space-time could be decisive and explain why the phenomenon is so rare.

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If PK-able persons can control also ordinary magnetic fields created by ordinary charges then one can consider an experiment in which PK-able person tries to affect the state of an ordinary super conductor.

The simplest experimental proof for the wormhole flux tube idea is to make them visible. One could achieve the situation in which atoms are condensed on wormhole flux tubes and form exotic atoms so that also electronic alchemy occurs: one can hardly imagine more dramatic proof of the concept! A second possibility is the interaction of laser light with wormhole flux tubes if the proposed explanation of phantom DNA effect is correct.

Also an experiment in which PK-able person tries to affect the motion of ORMEs [H9] (material possible containing exotic atoms predicted by TGD), could be considered. Actually, peculiar levitation effects have been claimed and also the proposed interpretations have been based on some kind of magnetic levitation and super conductivity. The original explanation was in terms of electronic super conductivity but on the light of recent results wormhole super conductivity seems to be a more plausible explanation. PK effect could be involved also with the claimed fluctuations in the weight of the ORMEs [H9] . PK effect might lead to an fluctuations in the high precision measurements of the value of gravitational constant. An interesting possibility is whether also ORMEs exhibit phantom ORME effect analogous to phantom DNA effect [I109] having explanation in terms of wormhole super conductivity.

Chapter 5

Bio-Systems as Super-Conductors: Part I

5.1 Introduction

In this chapter various TGD based ideas related to high T_c superconductivity and to the role of super-conductivity in bio-systems are studied. TGD inspired theory of consciousness provides several motivations for this.

1. Supra currents and Josephson currents provide excellent tools of bio-control allowing large space-time sheets to control the smaller space-time sheets. The predicted hierarchy of dark matter phases characterized by a large value of $\hbar$ and thus possessing scaled up Compton and de Broglie wavelengths allows to have quantum control of short scales by long scales utilizing de-coherence phase transition. Quantum criticality is the basic property of TGD Universe and quantum critical super-conductivity is therefore especially natural in TGD framework. The competing phases could be ordinary and large $\hbar$ phases and supra currents would flow along the boundary between the two phases.

2. It is possible to make a tentative identification of the quantum correlates of the sensory qualia quantum number increments associated with the quantum phase transitions of various macroscopic quantum systems [K41] and various kind of Bose-Einstein condensates and super-conductors are the most relevant ones in this respect.

3. The state basis for the fermionic Fock space spanned by N creation operators can be regarded as a Boolean algebra consisting of statements about N basic statements. Hence fermionic degreees of freedom could correspond to the Boolean mind whereas bosonic degrees of freedom would correspond to sensory experiencing and emotions. The integer valued magnetic quantum numbers (a purely TGD based effect) associated with the defect regions of super conductors of type I provide a very robust information storage mechanism and in defect regions fermionic Fock basis is natural. Hence not only fermionic super-conductors but also their defects are biologically interesting [K43, K81, K37].

5.1.1 General Ideas About Super-Conductivity In Many-Sheeted Space-Time

The notion of many-sheeted space-time alone provides a strong motivation for developing TGD based view about superconductivity and I have developed various ideas about high T_c superconductivity [D41] in parallel with ideas about living matter as a macroscopic quantum system. A further motivation and a hope for more quantitative modelling comes from the discovery of various non-orthodox super-conductors including high T_c superconductors [D41, D46, D3]. heavy fermion super-conductors and ferromagnetic superconductors [D40, D28, D17]. The standard BCS theory does not work for these super-conductors and the mechanism for the formation of Cooper pairs is not understood. There is experimental evidence that quantum criticality [D58] is a key feature of many non-orthodox super-conductors. TGD provides a conceptual framework and bundle of ideas making it possible to develop models for non-orthodox superconductors.

Quantum criticality, hierarchy of dark matters, and dynamical $\hbar$

Quantum criticality is the basic characteristic of TGD Universe and quantum critical superconductors provide an excellent test bed to develop the ideas related to quantum criticality into a more concrete form. The hypothesis that Planck constants in CD (causal diamond defined as the intersection of the future and past directed light-cones of M^4) and CP_2 degrees of freedom are dynamical possessing quantized spectrum given as integer multiples of minimum value of Planck constant [K40, K38] adds further content to the notion of quantum criticality.

After several alternatives I ended with the conjecture that the value of $\hbar$ is in the general case given by $\hbar = n \times \hbar_0$. Integer n characterizes a sub-algebra of super-symplectic algebra or related algebra with conformal structure characterized by the property that conformal weights are n-multiples of those of the full algebra. The sub-algebra is isomorphic with the full algebra so that a fractal hierarchy of sub-algebras is obtained. One obtains an infinite hierarchy of conformal gauge symmetry breaking hierarchies defined by the sequences of integers n_i dividing n_{i+1}.

The identification in terms of hierarchies of inclusions of hyper-finite factors of type II_1 is natural. Also the interpretation in terms of finite measurement resolution makes sense. As n increases the sub-algebra acting as conformal gauge symmetries is reduced so that some gauge degrees of freedom are transformed to physical ones. The transitions increasing n occur spontaneously since criticality is reduced. A good metaphor for TGD Universe is as a hill at the top of a hill at the top.... In biology this interpretation is especially interesting since living systems can be seen as systems doing their best to stay at criticality using metabolic energy feed as a tool to achieve this. Ironically, the increase of $\hbar$ would mean increase of measurement resolution and evolution!

The only coupling constant of the theory is Kähler coupling constant $\alpha_K = g_K^2/4\pi\hbar$, which appears in the definition of the Kähler function K characterizing the geometry of the configuration space of 3-surfaces (the "world of classical worlds"). The exponent of K defines vacuum functional analogous to the exponent of Hamiltonian in thermodynamics. The allowed value of $\alpha_K = g_K^2/4\pi\hbar$ should be analogous to critical temperature and determined by quantum criticality requirement. There are two possible interpretations for the hierarchy of Planck constants.

1. The actual value of $\hbar$ is always its standard value and value of $\alpha_K = g_K 2/4\pi\hbar$ is always its maximal value $\alpha_K(n = 1$ but there are n space-time sheets contributing the same value of Kähler action effectively scaling up the value of $\hbar_0$ to $n\hbar_0$ scaling down the value of $\alpha_K(1)$ to $\alpha_K(1)/n$. The n sheets would belong to n different conformal gauge equivalence classes of space-time surfaces connecting fixed 3-surfaces at opposite boundaries of CD. This interpretation is analogous to the introduction of the singular covering space of embedding space.

   One can of course ask whether all values $0 < m \leq n$ for the number of "actualized" sheets are possible. A possible interpretation would be in terms of charge fractionization.

2. One could also speak of genuine hierarchy of Planck constants $\hbar = n\hbar_0$ predicting a genuine hierarchy of Kähler coupling strengths $\alpha_K(n) = \alpha_K(n = 1)/n$. In thermodynamical analogy zero temperature is an accumulation of critical temperatures behaving like $1/n$. Intriguingly, in p-adic thermodynamics p-adic temperature is quantized for purely number theoretical reasons as $1/n$ multiples of the maximal p-adic temperature. Note that Kähler function is the analog of free energy. In this interpretation the n sheets are identified.

Phases with different values n behave like dark matter with respect to each other in the sense that they do not have direct interactions except at criticality for the phase transition changing the value of n to its multiple or divisor. In large $\hbar(CD)$ phases various quantum time and length scales are scaled up which means macroscopic and macro-temporal quantum coherence.

Number theoretic complexity argument favors the hypothesis that the integers n corresponding to Fermat polygons constructible using only ruler and compass and given as products $n_F = 2^k \prod_s F_s$, where $F_s = 2^{2^s} + 1$ are distinct Fermat primes, might be favored. The reason would be that quantum phase $q = exp(i\pi/n)$ is in this case expressible using only iterated square root operation by starting from rationals. The known Fermat primes correspond to $s = 0, 1, 2, 3, 4$ so that the hypothesis is very strong and predicts that p-adic length scales have satellite length scales given as multiples of n_F of fundamental p-adic length scale.

Contrary to the original hypothesis inspired by the requirement that gravitational coupling is renormalization group invariant, α_K does not seem to depend on p-adic prime whereas gravitational constant is proportional to L_p^2. The situation is saved by the assumption that gravitons correspond to the largest non-super-astrophysical Mersenne prime M_{127} so that gravitational coupling is effectively RG invariant in p-adic coupling constant evolution [L42].

$\hbar(CD)$ appears in the commutation and anti-commutation relations of various superconformal algebras. Kähler function codes for radiative corrections to the classical action, which makes possible to consider the possibility that higher order radiative corrections to functional integral vanish as one might expect at quantum criticality. For a given p-adic length scale space-time sheets with all allowed values of Planck constants are possible. Hence the spectrum of quantum critical fluctuations could in the ideal case correspond to the spectrum of Planck constants coding for the scaled up values of Compton lengths and other quantal lengths and times. If so, large $\hbar$ phases could be crucial for understanding of quantum critical superconductors, in particular high T_c superconductors.

A further great idea is that the transition to large $\hbar$ phase occurs when perturbation theory based on the expansion in terms of gauge coupling constant ceases to converge: Mother Nature would take care of the problems of theoretician. The transition to large $\hbar$ phase obviously reduces gauge coupling strength α so that higher orders in perturbation theory are reduced whereas the lowest order "classical" predictions remain unchanged. A possible quantitative formulation of the criterion is that maximal 2-particle gauge interaction strength parameterized as $Q_1Q_2\alpha$ satisfies the condition $Q_1Q_2\alpha \simeq 1$.

TGD thus predicts an infinite hierarchy of phases behaving like dark or partially dark matter with respect to the ordinary matter and each other [?] and the value of $\hbar$ is only one characterizer of these phases. These phases, especially so large $\hbar$ phase, seem to be essential for the understanding of even ordinary hadronic, nuclear and condensed matter physics [?, K97, K38]. This strengthens the motivations for finding whether dark matter might be involved with quantum critical superconductivity.

Cusp catastrophe serves as a metaphor for criticality. In the case of high T_c superconductivity temperature and doping are control variables and the tip of cusp is at maximum value of T_c. Critical region correspond to the cusp catastrophe. Quantum criticality suggests the generalization of the cusp to a fractal cusp. Inside the critical lines of cusp there are further cusps which corresponds to higher levels in the hierarchy of dark matters labeled by increasing values of $\hbar$ and they correspond to a hierarchy of subtle quantum coherent dark matter phases in increasing length scales. The proposed model for high T_c super-conductivity involves only single value of Planck constant but it might be that the full description involves very many values of them.

Many-sheeted space-time concept and ideas about macroscopic quantum phases

Many-sheeted space-time leads to obvious ideas concerning the realization of macroscopic quantum phases.

1. The dropping of particles to larger space-time sheets is a highly attractive mechanism of super-conductivity. If space-time sheets are thermally isolated, the larger space-time sheets could be at extremely low temperature and super-conducting.

2. The possibility of large $\hbar$ phases allows to give up the assumption that space-time sheets characterized by different p-adic length scales are thermally isolated. The scaled up versions of a given space-time sheet corresponding to a hierarchy of values of $\hbar$ are possible such that the scale of kinetic energy and magnetic interaction energy remain same for all these space-time sheets. For the scaled up variants of space-time sheet the critical temperature for superconductivity could be higher than room temperature.

3. The idea that wormhole contacts can form macroscopic quantum phases and that the interaction of ordinary charge carriers with the wormhole contacts feeding their gauge fluxes to larger space-time sheets could be responsible for the formation of Cooper pairs, have been

around for a decade [K121]. The rather recent realization that wormhole contacts can be actually regarded as space-time correlates for Higgs particles suggests also a new view about the photon massivation in super-conductivity.

4. Quantum classical correspondence has turned out be a very powerful idea generator. For instance, one can ask what are the space-time correlates for various notions of condensed matter such as phonons, BCS Cooper pairs, holes, etc...

5.1.2 TGD Inspired Model For High T_c Superconductivity

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

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

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

2. Usually magnetic field tends to destroy Cooper pairs since it tends to flip the spins of electrons of pair to same direction. In TGD flux quantization comes in rescue and magnetic fields favor the formation of Cooper pairs. If one has two parallel flux tubes with opposite directions of magnetic fluxes with large value of $h_{eff} = nh$, $S = 0$ Cooper pairs with even $L \geq 2$ are favored. This situation is encountered in systems near antiferromagnetic phase transition in small scales leading to formation of sequences of flux loops carrying Cooper pairs. Macroscopic super-conductivity results when the loops are reconnected to two long flux tubes with opposite fluxes. If the magnetic fluxes have same sign, $S = 1$ Cooper pairs with odd $L \geq 1$ are favored.

3. The higher critical temperature T_{c1} corresponds to a formation local configurations of parallel spins assigned to the holes of stripes giving rise to a local dipole fields with size scale of the order of the length of the stripe. Conducting electrons form Cooper pairs at the magnetic flux tube structures associated with these dipole fields. The presence of magnetic field favors Cooper pairs with spin $S = 1$. It took long time to realize that pairs of large h_{eff} magnetic flux tubes with fluxes in opposite directions are ideal for carrying Cooper pairs with members of the pair at the different flux tubes. Large spin interaction energy with magnetic field proportional to $h_{eff} = nh$ stablizes the pair.

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

5. Above T_c supra currents are possible only in the length scale of the flux tubes of the dipoles which is of the order of stripe length. The reconnections between neighboring flux tube structures induced by the transverse fluctuations give rise to longer flux tubes structures making possible finite conductivity. These occur with certain temperature dependent probability $p(T, L)$ depending on temperature and distance L between the stripes. By criticality $p(T, L)$ depends on the dimensionless variable $x = TL/\hbar$ only: $p = p(x)$. At critical temperature T_c transverse fluctuations have large amplitude and makes $p(x_c)$ so large that very long flux tubes are created and supra currents can run. The phenomenon is completely analogous to percolation [D5].

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

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

8. TGD suggests preferred values for $r = \hbar/\hbar_0$ and the applications to bio-systems favor powers of $r = 2^{11}$. $r = 2^{11}$ predicts that electron Compton length is of order atomic size scale. Bio-superconductivity could involve electrons with $r = 2^{22}$ having size characterized by the thickness of the lipid layer of cell membrane.

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

The model explains the observed ferromagnetic super-conductivity at quantum criticality [D40]. Since long flux tubes already exist, the overcritical transverse of fluctuations of the magnetic flux tubes inducing reconnections are now not responsible for the propagation of the super currents now. The should however provide the binding mechanism of $S = 1, L = 2$ Cooper pairs via the coupling of the fluctuations to excitation in the direction of flux tubes. I have considered effectively one-dimensional phonons in the direction of flux tubes as a candidates for this excitation. Spin density waves looks however a more realistic possibility. Also a modulated ferromagnetic phase consisting of stripes of opposite magnetization direction allows superconductivity [D40] and could be understood in terms of $S = 0$ Cooper pairs with electrons of the pair located at the neighboring stripes (flux tubes in TGD model.

5.1.3 Empirical Evidence For High T_c Superconductivity In Bio-Systems

There is evidence for super-conductivity in bio-systems. DNA should be insulator but under some circumstances it becomes conductor [I41] and perhaps even high T_c quantum critical super-conductor. Also evidence for Josephson effect has been reported [D24]. The so called ORMEs patented by Hudson [H9] are claimed to behave like superconductors: unfortunately the academic world has not taken these claims seriously enough to test them. The claimed properties of ORMEs conform with high quantum critical T_c super-conductivity and superfluidity. The strange findings about the strange quantal behavior of ionic currents through cell membranes [I63] suggest the presence of ionic supra currents. This evidence is discussed in the next chapter [K22].

5.2 General TGD Based View About Super-Conductivity

Today super-conductivity includes besides the traditional low temperature super-conductors many other non-orthodox ones [D54]. These unorthodox super-conductors carry various attributes such as cuprate, organic, dichalcogenide, heavy fermion, bismute oxide, ruthenate, antiferromagnetic and ferromagnetic. Mario Rabinowitz has proposed a simple phenomenological theory of super-fluidity and super-conductivity which helps non-specialist to get a rough quantitative overall view about super-conductivity [D54].

5.2.1 Basic Phenomenology Of Super-Conductivity

The following provides the first attempt by a non-professional to form an overall view about super-conductivity.

Basic phenomenology of super-conductivity

The transition to super-conductivity occurs at critical temperature T_c and involves a complete loss of electrical resistance. Super-conductors expel magnetic fields (Meissner effect) and when the external magnetic field exceeds a critical value H_c super-conductivity is lost either completely or partially. In the transition to super-conductivity specific heat has singularity. For long time magnetism and super-conductivity were regarded as mutually exclusive phenomena but the discovery of ferromagnetic super-conductors [D40, D17] has demonstrated that reality is much more subtle.

The BCS theory developed by Bardeen, Cooper, and Schrieffer in 1957 provides a satisfactory model for low T_c super-conductivity in terms of Cooper pairs. The interactions of electrons with the crystal lattice induce electron-electron interaction binding electrons to Cooper pairs at sufficiently low temperatures. The electrons of Cooper pair are at the top of Fermi sphere (otherwise they cannot interact to form bound states) and have opposite center of mass momenta and spins. The binding creates energy gap E_g determining the critical temperature T_c. The singularity of the specific heat in the transition to super-conductivity can be understood as being due to the loss of thermally excitable degrees of freedom at critical temperature so that heat capacity is reduced exponentially. BCS theory has been successful in explaining the properties of low temperature super conductors but the high temperature super-conductors discovered in 1986 and other non-orthodox superconductors discovered later remain a challenge for theorists.

The reasons why magnetic fields tend to destroy super-conductivity is easy to understand. Lorentz force induces opposite forces to the electrons of Cooper pair since the momenta are opposite. Magnetic field tends also to turn the spins in the same direction. The super-conductivity is destroyed in fields for which the interaction energy of magnetic moment of electron with field is of the same order of magnitude as gap energy $E_g \sim T_c$: $e\hbar H_c/2m \sim T_c$.

If spins are parallel, the situation changes since only Lorentz force tends to destroy the Cooper pair. In high T_c super-conductors this is indeed the case: electrons are in spin triplet state ($S = 1$) and the net orbital angular momentum of Cooper pair is $L = 2$. The fact that orbital state is not $L = 0$ state makes high T_c super-conductors much more fragile to the destructive effect of impurities than conventional super-conductors (due to the magnetic exchange force between electrons responsible for magnetism). Also the Cooper pairs of ^3He superfluid are in spin triplet state but have $S = 0$.

The observation that spin triplet Cooper pairs might be possible in ferro-magnets stimulates the question whether ferromagnetism and super-conductivity might tolerate each other after all, and the answer is affirmative [D17]. The article [D40] provides an enjoyable summary of experimental discoveries.

Basic parameters of super-conductors from universality?

Super conductors are characterized by certain basic parameters such as critical temperature T_c and critical magnetic field H_c, densities n_c and n of Cooper pairs and conduction electrons, gap energy E_g, correlation length ξ and magnetic penetration length λ. The super-conductors are highly complex systems and calculation of these parameters from BCS theory is either difficult or impossible.

It has been suggested [D54] that these parameters might be more or less universal so that they would not depend on the specific properties of the interaction responsible for the formation of Cooper pairs. The motivation comes from the fact that the properties of ordinary Bose-Einstein condensates do not depend on the details of interactions. This raises the hope that these parameters might be expressible in terms of some basic parameters such as T_c and the density of conduction electrons allowing to deduce Fermi energy E_F and Fermi momentum k_F if Fermi surface is sphere. In [D54] formulas for the basic parameters are indeed suggested based on this of argumentation assuming that Cooper pairs form a Bose-Einstein condensate.

1. The most important parameters are critical temperature T_c and critical magnetic field H_c in principle expressible in terms of gap energy. In [D54] the expression for T_c is deduced from the condition that the de Broglie wavelength λ must satisfy in supra phase the condition

$$\lambda \geq 2d = 2(\frac{n_c}{g})^{-1/D} \tag{5.2.1}$$

   guaranteeing the quantum overlap of Cooper pairs. Here n_c is the density of Bose-Einstein condensate of Cooper pairs and g is the number of spin states and D the dimension of the condensate. This condition follows also from the requirement that the number of particles per energy level is larger than one (Bose-Einstein condensation).

   Identifying this expression with the de Broglie wavelength $\lambda = \hbar/\sqrt{2mE}$ at thermal energy $E = (D/2)T_c$, where D is the number of degrees of freedom, one obtains

$$T_c \leq \frac{h^2}{4Dm}(\frac{n_c}{g})^{2/D} \ . \tag{5.2.2}$$

   m denotes the effective mass of super current carrier and for electron it can be even 100 times the bare mass of electron. The reason is that the electron moves is somewhat like a person trying to move in a dense crowd of people, and is accompanied by a cloud of charge carriers increasing its effective inertia. In this equation one can consider the possibility that Planck constant is not the ordinary one. This obviously increases the critical temperature unless n_c is scaled down in same proportion in the phase transition to large $\hbar$ phase.

2. The density of n_c Cooper pairs can be estimated as the number of fermions in Fermi shell at E_F having width Δk deducible from kT_c. For $D = 3$-dimensional spherical Fermi surface one has

$$\begin{aligned} n_c &= \frac{1}{2}\frac{4\pi k_F^2\Delta k}{\frac{4}{3}\pi k_F^3}n \ , \\ kT_c &= E_F - E(k_F - \Delta k) \simeq \frac{h^2 k_F \Delta k}{m} \ . \end{aligned} \tag{5.2.3}$$

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

$$n_c(D) = \frac{D}{2}\frac{T_c}{E_F}n(D) \ . \tag{5.2.4}$$

   The dimensionless coefficient is expressible solely in terms of n and effective mass m. In [D54] it is demonstrated that the inequality 5.3.2 replaced with equality when combined with 5.3.4 gives a satisfactory fit for 16 super-conductors used as a sample.

   Note that the Planck constant appearing in E_F and T_c in Eq. 5.3.4 must correspond to ordinary Planck constant $\hbar_0$. This implies that equations 5.3.2 and 5.3.4 are consistent within orders of magnitudes. For $D = 2$, which corresponds to high T_c superconductivity, the substitution of n_c from Eq. 5.3.4 to Eq. 5.3.2 gives a consistency condition from which n_c disappears completely. The condition reads as

$$n\lambda_F^2 = \pi = 4g \ .$$

   Obviously the equation is not completely consistent.

3. The magnetic penetration length λ is expressible in terms of density n_c of Cooper pairs as

$$\lambda^{-2} = \frac{4\pi e^2 n_c}{m_e} \ . \tag{5.2.5}$$

The ratio $\kappa \equiv \frac{\lambda}{\xi}$ determines the type of the super conductor. For $\kappa < \frac{1}{\sqrt{2}}$ one has type I super conductor with defects having negative surface energy. For $\kappa \geq \frac{1}{\sqrt{2}}$ one has type II super conductor and defects have positive surface energy. Super-conductors of type I this results in complex stripe like flux patterns maximizing their area near criticality. The super-conductors of type II have $\kappa > 1/\sqrt{2}$ and the surface energy is positive so that the flux penetrates as flux quanta minimizing their area at lower critical value H_{c_1} of magnetic field and completely at higher critical value H_{c_2} of magnetic field. The flux quanta contain a core of size ξ carrying quantized magnetic flux.

4. Quantum coherence length ξ can be roughly interpreted as the size of the Cooper pair or as the size of the region where it is sensible to speak about the phase of wave function of Cooper pair. For larger separations the phases of wave functions are un-correlated. The values of ξ vary in the range $10^3 - 10^4$ Angstrom for low T_c super-conductors and in the range $5 - 20$ Angstrom for high T_c super-conductors (assuming that they correspond to ordinary $\hbar$!) the ratio of these coherence lengths varies in the range $[50 - 2000]$, with upper bound corresponding to $n_F = 2^{11}$ for $\hbar$. This would give range $1 - 2$ microns for the coherence lengths of high T_c super-conductors with lowest values of coherence lengths corresponding to the highest values of coherence lengths for low temperatures super conductors.

Uncertainty Principle $\delta E \delta t = \hbar/2$ using $\delta E = E_g \equiv 2\Delta$, $\delta t = \xi/v_F$, gives an order of magnitude estimate for ξ differing only by a numerical factor from the result of a rigorous calculation given by

$$\xi = \frac{4\hbar v_F}{E_g} \ . \tag{5.2.6}$$

E_g is apart from a numerical constant equal to T_c: $E_g = nT_c$. Using the expression for v_F and T_c in terms of the density of electrons, one can express also ξ in terms of density of electrons.

For instance, BCS theory predicts $n = 3.52$ for metallic super-conductors and $n = 8$ holds true for cuprates [D54]. For cuprates one obtains $\xi = 2n^{-1/3}$ [D54]. This expression can be criticized since cuprates are Mott insulators and it is not at all clear whether a description as Fermi gas makes sense. The fact that high T_c super-conductivity involves breakdown of anti-ferromagnetic order might justify the use of Fermi gas description for conducting holes resulting in the doping.

For large $\hbar$ the value of ξ would scale up dramatically if deduced theoretically from experimental data using this kind of expression. If the estimates for ξ are deduced from v_F and T_c purely calculationally as seems to be the case, the actual coherence lengths would be scaled up by a factor $\hbar/\hbar_0 = n_F$ if high T_c super-conductors correspond to large $\hbar$ phase. As also found that this would also allow to understand the high critical temperature.

5.2.2 Universality Of The Parameters In TGD Framework

Universality idea conforms with quantum criticality of TGD Universe. The possibility to express everything in terms of density of critical temperature coding for the dynamics of Cooper pair formation and the density charge carriers would make it also easy to understand how p-adic scalings and transitions to large $\hbar$ phase affect the basic parameters. The possible problem is that the replacement of inequality of Eq. 5.3.2 with equality need not be sensible for large $\hbar$ phases. It will be found that in many-sheeted space-time T_c does not directly correspond to the gap energy and the universality of the critical temperature follows from the p-adic length scale hypothesis.

The effect of p-adic scaling on the parameters of super-conductors

p-Adic fractality expresses as $n \propto 1/L^3(k)$ would allow to deduce the behavior of the various parameters as function of the p-adic length scale and naïve scaling laws would result. For instance, E_g and T_c would scale as $1/L^2(k)$ if one assumes that the density n of particles at larger space-time sheets scales p-adically as $1/L^3(k)$. The basic implication would be that the density of Cooper pairs and thus also T_c would be reduced very rapidly as a function of the p-adic length scale. Without thermal isolation between these space-time sheets and hight temperature space-time sheets there would not be much hopes about high T_c super-conductivity.

In the scaling of Planck constant basic length scales scale up and the overlap criterion for super-conductivity becomes easy to satisfy unless the density of electrons is reduced too dramatically. As found, also the critical temperature scales up so that there are excellent hopes of obtain high T_c super-conductor in this manner. The claimed short correlation lengths are not a problem since they are calculational quantities.

It is of interest to study the behavior of the various parameters in the transition to the possibly existing large $\hbar$ variant of super-conducting electrons. Also small scalings of $\hbar$ are possible and the considerations to follow generalize trivially to this case. Under what conditions the behavior of the various parameters in the transition to large $\hbar$ phase is dictated by simple scaling laws?

1. *Scaling of T_c and E_g*

T_c and E_g remain invariant if E_g corresponds to a purely classical interaction energy remaining invariant under the scaling of $\hbar$. This is not the case for BCS super-conductors for which the gap energy E_g has the following expression.

$$\begin{aligned}
E_g &= \hbar\omega_c exp(-1/X) \ , \\
X &= n(E_F)U_0 = \frac{3}{2}N(E_F)\frac{U_0}{E_F} \ , \\
n(E_F) &= \frac{3}{2}\frac{N(E_F)}{E_F} \ . \\
\omega_c &= \omega_D = (6\pi^2)^{1/3}c_s n_n^{1/3} \ .
\end{aligned} \tag{5.2.7}$$

Here ω_c is the width of energy region near E_F for which "phonon" exchange interaction is effective. n_n denotes the density of nuclei and c_s denotes sound velocity.

$N(E_F)$ is the total number of electrons at the super-conducting space-time sheet. U_0 would be the parameter characterizing the interaction strength of of electrons of Cooper pair and should not depend on $\hbar$. For a structure of size $L \sim 1\ \mu$ m one would have $X \sim n_a 10^{12}\frac{U_0}{E_F}$, n_a being the number of exotic electrons per atom, so that rather weak interaction energy U_0 can give rise to $E_g \sim \omega_c$.

The expression of ω_c reduces to Debye frequency ω_D in BCS theory of ordinary super conductivity. If c_s is proportional to thermal velocity $\sqrt{T_c/m}$ at criticality and if n_n remains invariant in the scaling of $\hbar$, Debye energy scales up as $\hbar$. This can imply that $E_g > E_F$ condition making scaling non-sensible unless one has $E_g \ll E_F$ holding true for low T_c super-conductors. This kind of situation would *not* require large $\hbar$ phase for electrons. What would be needed that nuclei and phonon space-time sheets correspond to large $\hbar$ phase.

What one can hope is that E_g scales as $\hbar$ so that high T_c superconductor would result and the scaled up T_c would be above room temperature for $T_c > .15$ K. If electron is in ordinary phase X is automatically invariant in the scaling of $\hbar$. If not, the invariance reduces to the invariance of U_0 and E_F under the scaling of $\hbar$. If n scales like $1/\hbar^D$, E_F and thus X remain invariant. U_0 as a simplified parameterization for the interaction potential expressible as a tree level Feynman diagram is expected to be in a good approximation independent of $\hbar$.

It will be found that in high T_c super-conductors, which seem to be quantum critical, a high T_c variant of phonon mediated superconductivity and exotic superconductivity could be competing. This would suggest that the phonon mediated superconductivity corresponds to a large $\hbar$ phase for nuclei scaling ω_D and T_c by a factor $r = \hbar/\hbar_0$.

Since the total number $N(E_F)$ of electrons at larger space-time sheet behaves as $N(E_F) \propto E_F^{D/2}$, where D is the effective dimension of the system, the quantity $1/X \propto E_F/n(E_F)$ appearing in the expressions of the gap energy behaves as $1/X \propto E_F^{-D/2+1}$. This means that at the limit of vanishing electron density $D=3$ gap energy goes exponentially to zero, for $D=2$ it is constant, and for $D=1$ it goes zero at the limit of small electron number so that the formula for gap energy reduces to $E_g \simeq \omega_c$. These observations suggests that the super-conductivity in question should be 2- or 1-dimensional phenomenon as in case of magnetic walls and flux tubes.

2. Scaling of ξ and λ

If n_c for high T_c super-conductor scales as $1/\hbar^D$ one would have $\lambda \propto \hbar^{D/2}$. High T_c property however suggests that the scaling is weaker. ξ would scale as $\hbar$ for given v_F and T_c. For $D=2$ case the this would suggest that high T_c super-conductors are of type I rather than type II as they would be for ordinary $\hbar$. This conforms with the quantum criticality which would be counterpart of critical behavior of super-conductors of type I in nearly critical magnetic field.

3. Scaling of H_c and B

The critical magnetization is given by

$$H_c(T) = \frac{\Phi_0}{\sqrt{8}\pi\xi(T)\lambda(T)} , \qquad (5.2.8)$$

where Φ_0 is the flux quantum of magnetic field proportional to $\hbar$. For $D=2$ and $n_c \propto \hbar^{-2}$ $H_c(T)$ would not depend on the value of $\hbar$. For the more physical dependence $n_c \propto \hbar^{-2+\epsilon}$ one would have $H_c(T) \propto \hbar^{-\epsilon}$. Hence the strength of the critical magnetization would be reduced by a factor $2^{-11\epsilon}$ in the transition to the large $\hbar$ phase with $n_F = 2^{-11}$.

Magnetic flux quantization condition is replaced by

$$\int 2eBdS = n\hbar 2\pi \ . \qquad (5.2.9)$$

B denotes the magnetic field inside super-conductor different from its value outside the super-conductor. By the quantization of flux for the non-super-conducting core of radius ξ in the case of super-conductors of type II $eB = \hbar/\xi^2$ holds true so that B would become very strong since the thickness of flux tube would remain unchanged in the scaling.

5.2.3 Quantum Criticality And Super-Conductivity

The notion of quantum criticality has been already discussed in introduction. An interesting prediction of the quantum criticality of entire Universe also gives naturally rise to a hierarchy of macroscopic quantum phases since the quantum fluctuations at criticality at a given level can give rise to higher level macroscopic quantum phases at the next level. A metaphor for this is a fractal cusp catastrophe for which the lines corresponding to the boundaries of cusp region reveal new cusp catastrophes corresponding to quantum critical systems characterized by an increasing length scale of quantum fluctuations.

Dark matter hierarchy could correspond to this kind of hierarchy of phases and long ranged quantum slow fluctuations would correspond to space-time sheets with increasing values of $\hbar$ and size. Evolution as the emergence of modules from which higher structures serving as modules at the next level would correspond to this hierarchy. Mandelbrot fractal with inversion analogous to a transformation permuting the interior and exterior of sphere with zooming revealing new worlds in Mandelbrot fractal replaced with its inverse would be a good metaphor for what quantum criticality would mean in TGD framework.

How the quantum criticality of superconductors relates to TGD quantum criticality

There is empirical support that super-conductivity in high T_c super-conductors and ferromagnetic systems [D40, D28] is made possible by quantum criticality [D58]. In the experimental situation quantum criticality means that at sufficiently low temperatures quantum rather than thermal fluctuations are able to induce phase transitions. Quantum criticality manifests itself as fractality and simple scaling laws for various physical observables like resistance in a finite temperature range and also above the critical temperature. This distinguishes sharply between quantum critical super conductivity from BCS type super-conductivity. Quantum critical super-conductivity also exists in a finite temperature range and involves the competition between two phases.

The absolute quantum criticality of the TGD Universe maps to the quantum criticality of subsystems, which is broken by finite temperature effects bringing dissipation and freezing of quantum fluctuations above length and time scales determined by the temperature so that scaling laws hold true only in a finite temperature range.

Reader has probably already asked what quantum criticality precisely means. What are the phases which compete? An interesting hypothesis is that quantum criticality actually corresponds to criticality with respect to the phase transition changing the value of Planck constant so that the competing phases would correspond to different values of $\hbar$. In the case of high T_c super-conductors (anti-ferromagnets) the fluctuations can be assigned to the magnetic flux tubes of the dipole field patterns generated by rows of holes with same spin direction assignable to the stripes. Below T_c fluctuations induce reconnections of the flux tubes and a formation of very long flux tubes and make possible for the supra currents to flow in long length scales below T_c. Percolation type phenomenon is in question. The fluctuations of the flux tubes below $T_{c1} > T_c$ induce transversal phonons generating the energy gap for $S = 1$ Cooper pairs. $S = 0$ Cooper pairs are predicted to stabilize below T_c.

Scaling up of de Broglie wave lengths and criterion for quantum overlap

Compton lengths and de Broglie wavelengths are scaled up by an integer n, whose preferred values correspond to $n_F = 2^k \prod_s F_s$, where $F_s = 2^{2^s} + 1$ are distinct Fermat primes. In particular, $n_F = 2^{k11}$ seem to be favored in living matter. The scaling up means that the overlap condition $\lambda \geq 2d$ for the formation of Bose-Einstein condensate can be satisfied and the formation of Cooper pairs becomes possible. Thus a hierarchy of large $\hbar$ super-conductivities would be associated with to the dark variants of ordinary particles having essentially same masses as the ordinary particles.

Unless one assumes fractionization, the invariance of $E_F \propto \hbar_{eff}^2 n^{2/3}$ in $\hbar$ increasing transition would require that the density of Cooper pairs in large $\hbar$ phase is scaled down by an appropriate factor. This means that supra current intensities, which are certainly measurable quantities, are also scaled down. Of course, it could happen that E_F is scaled up and this would conform with the scaling of the gap energy.

Quantum critical super-conductors in TGD framework

For quantum critical super-conductivity in heavy fermions systems, a small variation of pressure near quantum criticality can destroy ferromagnetic (anti-ferromagnetic) order so that Curie (Neel) temperature goes to zero. The prevailing spin fluctuation theory [D14] assumes that these transitions are induced by long ranged and slow spin fluctuations at critical pressure P_c. These fluctuations make and break Cooper pairs so that the idea of super-conductivity restricted around critical point is indeed conceivable.

Heavy fermion systems, such as cerium-indium alloy $CeIn_3$ are very sensitive to pressures and a tiny variation of density can drastically modify the low temperature properties of the systems. Also other systems of this kind, such as $CeCu_2Ge_2$, $CeIn_3$, $CePd_2Si_2$ are known [D40, D17]. In these cases super-conductivity appears around anti-ferromagnetic quantum critical point.

The last experimental breakthrough in quantum critical super-conductivity was made in Grenoble [D28]. URhGe alloy becomes super-conducting at $T_c = .280$ K, loses its super-conductivity at $H_c = 2$ Tesla, and becomes again super-conducting at $H_c = 12$ Tesla and loses its super-conductivity again at $H = 13$ Tesla. The interpretation is in terms of a phase transition changing the magnetic order inducing the long range spin fluctuations.

TGD based models of atomic nucleus [K97] and condensed matter [K38] assume that weak gauge bosons with Compton length of order atomic radius play an essential role in the nuclear and condensed matter physics. The assumption that condensed matter nuclei possess anomalous weak charges explains the repulsive core of potential in van der Waals equation and the very low compressibility of condensed matter phase as well as various anomalous properties of water phase, provide a mechanism of cold fusion and sono-fusion, etc. [K38, K36]. The pressure sensitivity of these systems would directly reflect the physics of exotic quarks and electro-weak gauge bosons.

A possible mechanism behind the phase transition to super-conductivity could be the scaling up of the sizes of the space-time sheets of nuclei.

Also the electrons of Cooper pair (and only these) could make a transition to large $\hbar$ phase. This transition would induce quantum overlap having geometric overlap as a space-time correlate. The formation of flux tubes between neighboring atoms would be part of the mechanism. For instance, the criticality condition $4n^2\alpha = 1$ for BE condensate of n Cooper pairs would give $n = 6$ for the size of a higher level quantum unit possibly formed formed from Cooper pairs. If one does not assume invariance of energies obtained by fractionization of principal quantum number, this transition has dramatic effects on the spectrum of atomic binding energies scaling as $1/\hbar^2$ and practically universal spectrum of atomic energies would result [K36] not depending much on nuclear charge. It seems that this prediction is non-physical.

Quantum critical super-conductors resemble superconductors of type I with $\lambda \ll \xi$ for which defects near thermodynamical criticality are complex structures looking locally like stripes of thickness λ. These structures are however dynamical in super-conducting phase. Quite generally, long range quantum fluctuations due to the presence of two competing phases would manifest as complex dynamical structures consisting of stripes and their boundaries. These patterns are dynamical rather than static as in the case of ordinary spin glass phase so that quantum spin glass or 4-D spin glass is a more appropriate term. The breaking of classical non-determinism for vacuum extremals indeed makes possible space-time correlates for quantum non-determinism and this makes TGD Universe a 4-dimensional quantum spin glass.

Could quantum criticality make possible new kinds of high T_c super-conductors?

The transition to large $\hbar = r\hbar_0$ phase increases various length scales by r and makes possible long range correlations even at high temperatures. Hence the question is whether large $\hbar$ phase could correspond to ordinary high T_c super-conductivity. If this were the case in the case of ordinary high T_c super-conductors, the actual value of coherence length ξ would vary in the range $5-20$ Angstrom scaled up by a factor r. For effectively D-dimensional super-conductor The density of Cooper pairs would be scaled down by an immensely small factor $1/r^D$ from its value deduced from Fermi energy.

Large $\hbar$ phase for some nuclei might be involved and make possible large space-time sheets of size at least of order of ξ at which conduction electrons forming Cooper pairs would topologically condense like quarks around hadronic space-time sheets (in [K38] a model of water as a partially dark matter with one fourth of hydrogen ions in large $\hbar$ phase is developed).

Consider for a moment the science fictive possibility that super conducting electrons for some quantum critical super-conductors to be discovered or already discovered correspond to large $\hbar$ phase with $\hbar = r\hbar_0$ keeping in mind that this affects only quantum corrections in perturbative approach but not the lowest order classical predictions of quantum theory. For $r \simeq n2^{k11}$ with $(n,k) = (1,1)$ the size of magnetic body would be $L(149) = 5$ nm, the thickness of the lipid layer of cell membrane. For $(n,k) = (1,2)$ the size would be $L(171) = 10$ μm, cell size. If the density of Cooper pairs is of same order of magnitude as in case of ordinary super conductors, the critical temperature is scaled up by 2^{k11}. Already for $k = 1$ the critical temperature of 1 K would be scaled up to $4n^2 \times 10^6$ K if n_c is not changed. This assumption is not consistent with the assumption that Fermi energy remains non-relativistic. For $n = 1$ $T_c = 400$ K would be achieved for $n_c \rightarrow 10^{-6}n_c$, which looks rather reasonable since Fermi energy transforms as $E_F \rightarrow 8 \times 10^3 E_F$ and remains non-relativistic. H_c would scale down as $1/\hbar$ and for $H_c = .1$ Tesla the scaled down critical field would be $H_c = .5 \times 10^{-4}$ Tesla, which corresponds to the nominal value of the Earth's magnetic field.

Quantum critical super-conductors become especially interesting if one accepts the identification of living matter as ordinary matter quantum controlled by macroscopically quantum coherent dark matter. One of the basic hypothesis of TGD inspired theory of living matter is that the magnetic flux tubes of the Earth's magnetic field carry a super-conducting phase and the spin triplet Cooper pairs of electrons in large $\hbar$ phase might realize this dream. That the value of Earth's magnetic field is near to its critical value could have also biological implications.

5.2.4 Space-Time Description Of The Mechanisms OfSuper-Conductivity

The application of ideas about dark matter to nuclear physics and condensed matter suggests that dark color and weak forces should be an essential element of the chemistry and condensed matter physics. The continual discovery of new super-conductors, in particular of quantum critical superconductors, suggests that super-conductivity is not well understood. Hence super-conductivity provides an obvious test for these ideas. In particular, the idea that wormhole contacts regarded as parton pairs living at two space-time sheets simultaneously, provides an attractive universal mechanism for the formation of Cooper pairs and is not so far-fetched as it might sound first.

Leading questions

It is good to begin with a series of leading questions. The first group of questions is inspired by experimental facts about super-conductors combined with TGD context.

1. The work of Rabinowitch [D54] suggests that that the basic parameters of super-conductors might be rather universal and depend on T_c and conduction electron density only and be to a high degree independent of the mechanism of super-conductivity. This is in a sharp contrast to the complexity of even BCS model with its somewhat misty description of the phonon exchange mechanism.
Questions: Could there exist a simple universal description of various kinds of super-conductivities?

2. The new super-conductors possess relatively complex chemistry and lattice structure.
Questions: Could it be that complex chemistry and lattice structure makes possible something very simple describable in terms of quantum criticality. Could it be that the transversal oscillations magnetic flux tubes allow to understand the formation of Cooper pairs at T_{c1} and their reconnections generating very long flux tubes the emergence of supra currents at T_c?

3. The effective masses of electrons in ferromagnetic super-conductors are in the range of 10-100 electron masses [D40] and this forces to question the idea that ordinary Cooper pairs are current carriers.
Questions: Can one consider the possibility that the p-adic length scale of say electron can vary so that the actual mass of electron could be large in condensed matter systems? For quarks and neutrinos this seems to be the case [K56, K66]. Could it be that the Gaussian Mersennes $(1+i)^k-1$, $k=151,157,163,167$ spanning the p-adic lengthscale range 10 nm-2.5 μm very relevant from the point of view of biology correspond to p-adic length especially relevant for super-conductivity?

Second group of questions is inspired by quantum classical correspondence.

1. Quantum classical correspondence in its strongest form requires that bound state formation involves the generation of flux tubes between bound particles. The weaker form of the principle requires that the particles are topologically condensed at same space-time sheet. In the case of Cooper pairs in ordinary superconductors the length of join along boundaries bonds between electrons should be of order 10^3-10^4 Angstroms. This looks rather strange and it seems that the latter option is more sensible.
Questions: Could quantum classical correspondence help to identify the mechanism giving rise to Cooper pairs?

2. Quantum classical correspondence forces to ask for the space-time correlates for the existing quantum description of phonons.
Questions: Can one assign space-time sheets with phonons or should one identify them as oscillations of say space-time sheets at which atoms are condensed? Or should the microscopic description of phonons in atomic length scales rely on the oscillations of wormhole contacts connecting atomic space-time sheets to these larger space-time sheets? The identification of phonons as wormhole contacts would be completely analogous to the similar identification of gauge bosons except that phonons would appear at higher levels of the hierarchy of space-time sheets and would be emergent in this sense. As a matter fact, even gauge bosons as

pairs of fermion and anti-fermion are emergent structures in TGD framework and this plays fundamental role in the construction of QFT limit of TGD in which bosonic part of action is generated radiatively so that all coupling constants follow as predictions [?]. Could Bose-Einstein condensates of wormhole contacts be relevant for the description of super-conductors or more general macroscopic quantum phases?

The third group of questions is inspired by the new physics predicted or by TGD.

1. TGD predicts a hierarchy of macroscopic quantum phases with large Planck constant. Questions: Could large values of Planck constant make possible exotic electronic super-conductivities? Could even nuclei possess large $\hbar$ (super-fluidity)?

2. TGD predicts that classical color force and its quantal counterpart are present in all length scales.
Questions: Could color force, say color magnetic force which play some role in the formation of Cooper pair. The simplest model of pair is as a space-time sheet with size of order ξ so that the electrons could be "outside" the background space-time. Could the Coulomb interaction energy of electrons with positively charged wormhole throats carrying parton numbers and feeding em gauge flux to the large space-time sheet be responsible for the gap energy? Could wormhole throats carry also quark quantum numbers. In the case of single electron condensed to single space-time sheet the em flux could be indeed fed by a pair of $u\overline{u}$ and $\overline{d}d$ type wormhole contacts to a larger space-time sheet. Could the wormhole contacts have a net color? Could the electron space-time sheets of the Cooper pair be connected by long color flux tubes to give color singlets so that dark color force would be ultimately responsible for the stability of Cooper pair?

3. Suppose that one takes seriously the ideas about the possibility of dark weak interactions with the Compton scale of weak bosons scaled up to say atomic length scale so that weak bosons are effectively massless below this length scale [K38].
Questions: Could the dark weak length scale which is of order atomic size replace lattice constant in the expression of sound velocity? What is the space-time correlate for sound velocity?

Photon massivation, coherent states of Cooper pairs, and wormhole contacts

The existence of wormhole contacts is one of the most stunning predictions of TGD. First I realized that wormhole contacts can be regarded as parton-antiparton pairs with parton and antiparton assignable to the light-like causal horizons accompanying wormhole contacts. Then came the idea that Higgs particle could be identified as a wormhole contact. It was soon followed by the identification all bosonic states as wormhole contacts [K56]. Finally I understood that this applies also to their super-symmetric partners, which can be also fermion [?]. Fermions and their super-partners would in turn correspond to wormhole throats resulting in the topological condensation of small deformations of CP_2 type vacuum extremals with Euclidian signature of metric to the background space-time sheet. This framework opens the doors for more concrete models of also super-conductivity involving the effective massivation of photons as one important aspect in the case of ordinary super-conductors.

There are two types of wormhole contacts. Those of first type correspond to elementary bosons. Wormhole contacts of second kind are generated in the topological condensation of space-time sheets carrying matter and form a hierarchy. Classical radiation fields realized in TGD framework as oscillations of space-time sheets would generate wormhole contacts as the oscillating space-time sheet develops contacts with parallel space-time sheets (recall that the distance between space-time sheets is of order CP_2 size). This realizes the correspondence between fields and quanta geometrically. Phonons could also correspond to wormhole contacts of this kind since they mediate acoustic oscillations between space-time sheets and the description of the phonon mediated interaction between electrons in terms of wormhole contacts might be useful also in the case of super-conductivity. Bose-Einstein condensates of wormhole contacts might be highly relevant for the formation of macroscopic quantum phases. The formation of a coherent state of wormhole contacts would be the counterpart for the vacuum expectation value of Higgs.

The notions of coherent states of Cooper pairs and of charged Higgs challenge the conservation of electromagnetic charge. The following argument however suggests that coherent states of wormhole contacts form only a part of the description of ordinary super-conductivity. The basic observation is that wormhole contacts with vanishing fermion number define space-time correlates for Higgs type particle with fermion and anti-fermion numbers at light-like throats of the contact.

The ideas that a genuine Higgs type photon massivation is involved with super-conductivity and that coherent states of Cooper pairs really make sense are somewhat questionable since the conservation of charge and fermion number is lost for coherent states. A further questionable feature is that a quantum superposition of many-particle states with widely different masses would be in question. These interpretational problems can be resolved elegantly in zero energy ontology [K28] in which the total conserved quantum numbers of quantum state are vanishing. In this picture the energy, fermion number, and total charge of any positive energy state are compensated by opposite quantum numbers of the negative energy state in geometric future. This makes possible to speak about superpositions of Cooper pairs and charged Higgs bosons separately in positive energy sector.

If this picture is taken seriously, super-conductivity can be seen as providing a direct support for both the hierarchy of scaled variants of standard model physics and for the zero energy ontology.

Space-time correlate for quantum critical superconductivity

The explicit model for high T_c super-conductivity relies on quantum criticality involving long ranged quantum fluctuations inducing reconnection of flux tubes of local (color) magnetic fields associated with parallel spins associated with stripes to form long flux tubes serving as wires along which Cooper pairs flow. Essentially [D5] [D5] type phenomenon would be in question. The role of the doping by holes is to make room for Cooper pairs to propagate by the reconnection mechanism: otherwise Fermi statistics would prevent the propagation. Too much doping reduces the number of current carriers, too little doping leaves too little room so that there exists some optimal doping. In the case of high T_c super-conductors quantum criticality corresponds to a quite wide temperature range, which provides support for the quantum criticality of TGD Universe. The probability $p(T)$ for the formation of reconnections is what matters and exceeds the critical value at T_c.

5.2.5 Super-Conductivity At Magnetic Flux Tubes

Super-conductivity at the magnetic flux tubes of magnetic flux quanta is one the basic hypothesis of the TGD based model of living matter. There is also evidence for magnetically mediated super-conductivity in extremely pure samples [D29]. The magnetic coupling was only observed at lattice densities close to the critical density at which long-range magnetic order is suppressed. Quantum criticality that long flux tubes serve as pathways along which Cooper pairs can propagate. In anti-ferromagnetic phase these pathways are short-circuited to closed flux tubes of local magnetic fields.

Almost the same model as in the case of high T_c and quantum critical super-conductivity applies to the magnetic flux tubes. Now the flux quantum contains BE condensate of exotic Cooper pairs interacting with wormhole contacts feeding the gauge flux of Cooper pairs from the magnetic flux quantum to a larger space-time sheet. The interaction of spin 1 Cooper pairs with the magnetic field of flux quantum orients their spins in the same direction. Large value of $\hbar$ guarantees thermal stability even in the case that different space-time sheets are not thermally isolated.

The understanding of gap energy is not obvious. The transversal oscillations of magnetic flux tubes generated by spin flips of electrons define the most plausible candidate for the counterpart of phonons. In this framework phonon like states identified as wormhole contacts would be created by the oscillations of flux tubes and would be a secondary phenomenon.

Large values of $\hbar$ allow to consider not only the Cooper pairs of electrons but also of protons and fermionic ions. Since the critical temperature for the formation of Cooper pairs is inversely proportional to the mass of the charge carrier, the replacement of electron with proton or ion would require a scaling of $\hbar$. If T_{c1} is proportional to $\hbar^2$, this requires scaling by $(m_p/m_e)^{1/2}$. For $T_{c1} \propto \hbar$ scaling by $m_p/m_e \simeq 2^{11}$ is required. This inspired idea that powers of 2^{11} could define favored values of $\hbar/\hbar_0$. This hypothesis is however rather ad hoc and turned out to be too restrictive.

Besides Cooper pairs also Bose-Einstein condensates of bosonic ions are possible in large $\hbar$ phase and would give rise to super-conductivity. TGD inspired nuclear physics predicts the existence of exotic bosonic counterparts of fermionic nuclei with given (A, Z) [L3], [L3].

Superconductors at the flux quanta of the Earth's magnetic field

Magnetic flux tubes and magnetic walls are the most natural candidates for super-conducting structures with spin triplet Cooper pairs. Indeed, experimental evidence relating to the interaction of ELF em radiation with living matter suggests that bio-super-conductors are effectively 1- or 2-dimensional. $D \leq 2$-dimensionality is guaranteed by the presence of the flux tubes or flux walls of, say, the magnetic field of Earth in which charge carries form bound states and the system is equivalent with a harmonic oscillator in transversal degrees of freedom.

The effect of Earth's magnetic field is completely negligible at the atomic space-time sheets and cannot make super conductor 1-dimensional. At cellular sized space-time sheets magnetic field makes possible transversal the confinement of the electron Cooper pairs in harmonic oscillator states but does not explain energy gap which should be at the top of 1-D Fermi surface. The critical temperature extremely low for ordinary value of $\hbar$ and either thermal isolation between space-time sheets or large value of $\hbar$ can save the situation.

An essential element of the picture is that topological quantization of the magnetic flux tubes occurs. In fact, the flux tubes of Earth's magnetic field have thickness of order cell size from the quantization of magnetic flux. The observations about the effects of ELF em fields on bio-matter [J25] suggest that similar mechanism is at work also for ions and in fact give very strong support for bio-super conductivity based on the proposed mechanism.

Energy gaps for superconducting magnetic flux tubes and walls

Besides the formation of Cooper pairs also the Bose-Einstein condensation of charge carriers to the ground state is needed in order to have a supra current. The stability of Bose-Einstein condensate requires an energy gap $E_{g,BE}$ which must be larger than the temperature at the magnetic flux tube.

Several energies must be considered in order to understand $E_{g,BE}$.

1. The Coulombic binding energy of Cooper pairs with the wormhole contacts feeding the em flux from magnetic flux tube to a larger space-time sheet defines an energy gap which is expected to be of order $E_{g,BE} = \alpha/L(k)$ giving $E_g \sim 10^{-3}$ eV for $L(167) = 2.5$ μm giving a rough estimate for the thickness of the magnetic flux tube of the Earth's magnetic field $B = .5 \times 10^{-4}$ Tesla.

2. In longitudinal degrees of freedom of the flux tube Cooper pairs can be described as particles in a one-dimensional box and the gap is characterized by the length L of the magnetic flux tube and the value of $\hbar$. In longitudinal degrees of freedom the difference between $n = 2$ and $n = 1$ states is given by $E_0(k_2) = 3h^2/4m_eL^2(k_2)$. Translational energy gap $E_g = 3E_0(k_2) = 3h^2/4m_eL^2(k_2)$ is smaller than the effective energy gap $E_0(k_1) - E_0(k_2) = h^2/4m_eL^2(k_1) - h^2/4m_eL^2(k_2)$ for $k_1 > k_2+2$ and identical with it for $k_1 = k_2+2$. For $L(k_2 = 151)$ the zero point kinetic energy is given by $E_0(151) = 20.8$ meV so that $E_{g,BE}$ corresponds roughly to a temperature of 180 K. For magnetic walls the corresponding temperature would be scaled by a factor of two to 360 K and is above room temperature.

3. Second troublesome energy gap relates to the interaction energy with the magnetic field. The magnetic interaction energy E_m of Cooper pair with the magnetic field consists of cyclotron term $E_c = n\hbar eB/m_e$ and spin-interaction term which is present only for spin triplet case and is given by $E_s = \pm\hbar eB/m_e$ depending on the orientation of the net spin with magnetic field. In the magnetic field $B_{end} = 2B_E/5 = .2$ Gauss ($B_E = .5$ Gauss is the nominal value of the Earth's magnetic field) explaining the effects of ELF em fields on vertebrate brain, this energy scale is $\sim 10^{-9}$ eV for $\hbar_0$ and $\sim 1.6 \times 10^{-5}$ eV for $\hbar = 2^{14} \times \hbar_0$.

The smallness of translational and magnetic energy gaps in the case of Cooper pairs at Earth's magnetic field could be seen as a serious obstacle.

1. Thermal isolation between different space-time sheets provides one possible resolution of the problem. The stability of the Bose-Einstein condensation is guaranteed by the thermal isolation of space-time if the temperature at the magnetic flux tube is below E_m. This can be achieved in all length scales if the temperature scales as the zero point kinetic energy in transversal degrees of freedom since it scales in the same manner as magnetic interaction energy.

2. The transition to large $\hbar$ phase could provide a more elegant way out of the difficulty. The criterion for a sequence of transitions to a large $\hbar$ phase could be easily satisfied if there is a large number of charge Cooper pairs at the magnetic flux tube. Kinetic energy gap remains invariant if the length of the flux tube scales as $\hbar$. If the magnetic flux is quantized as a multiple of $\hbar$ and flux tube thickness scales as $\hbar^2$, B must scale as $1/\hbar$ so that also magnetic energy remains invariant under the scaling. This would allow to have stability without assuming low temperature at magnetic flux tubes.

A new phase of matter in the temperature range between pseudo gap temperature and T_c?

Kram sent a link to a Science Daily popular article titled "High-Temperature Superconductor Spills Secret: A New Phase of Matter?" (see `http://tinyurl.com/49vnvsu`: see also `http://tinyurl.com/yb7rs3fs`). For more details see the article in Science [D25].

Zhi-Xun Shen of the Stanford Institute for Materials and Energy Science (SIMES), a joint institute of the Department of Energy's SLAC National Accelerator Laboratory and Stanford University, led the team of researchers, which discovered that in the temperature region between the pseudo gap temperature and genuine temperature for the transition to super-conducting phase there exists a new phase of matter. The new phase would not be super-conducting but would be characterized by an order of its own which remains to be understood. This phase would be present also in the super-conducting phase.

The announcement does not come as a complete surprise for me. A new phase of matter is what TGD inspired model of high T_c superconductivity indeed predicts. This phase would consist of Cooper pairs of electrons with a large value of Planck constant but associated with magnetic flux tubes with short length so that no macroscopic supra currents would be possible.

The transition to super-conducting phase involves long range fluctuations at quantum criticality and the analog of a phenomenon known as percolation (see `http://tinyurl.com/oytvosv`) [D5]. For instance, the phenomenon occurs for the filtering of fluids through porous materials. At critical threshold the entire filter suddenly wets as fluid gets through the filter. Now this phenomenon would occur for magnetic flux tubes carrying the Cooper pairs. At criticality the short magnetic flux tubes fuse by reconnection to form long ones so that supra currents in macroscopic scales become possible.

It is not clear whether this prediction is consistent with the finding of Shen and others. The simultaneous presence of short and long flux tubes in macroscopically super-conducting phase is certainly consistent with TGD prediction. The situation depends on what one means with super-conductivity. Is super-conductivity super-conductivity in macroscopic scales only or should one call also short scale super-conductivity not giving rise to macroscopic super currents as super-conductivity. In other words: do the findings of Shen's team prove that the electrons above gap temperature do not form Cooper pairs or only that there are no macroscopic supra currents?

Whether the model works as such or not is not a life and death question for the TGD based model. One can quite well imagine that the first phase transition increasing $\hbar$ does not yet produce electron Compton lengths long enough to guarantee that the overlap criterion for the formation of Cooper pairs is satisfied. The second phase transition increasing $\hbar$ would do this and also scale up the lengths of magnetic flux tubes making possible the flow of supra currents as such even without reconnections. Also reconnections making possible the formation of very long flux tubes could be involved and would be made possible by the increase in the length of flux tubes.

21-Micrometer mystery

21 micrometer radiation from certain red giant stars have perplexed astronomers for more than a decade [D8]. Emission forms a wide band (with width about 4 micrometers) in the infrared

spectrum, which suggests that it comes form a large complex molecule or a solid or simple molecules found around starts. Small molecules are ruled out since they produce narrow emission lines. The feature can be only observed in very precise evolutionary state, in the transition between red giant phase and planetary nebular state, in which star blows off dust that is rich in carbon compounds. There is no generally accepted explanation for 21-micrometer radiation.

One can consider several explanations based on p-adic length scale hypothesis and some explanations might relate to the wormhole based super-conductivity.

1. 21 micrometers corresponds to the photon energy of 59 meV which is quite near to the zero point point kinetic energy 61.5 meV of proton Cooper pair at $k = 139$ space-time sheet estimated from the formula

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

   Here the binding energy of the Cooper pair tending to reduce this estimate is neglected, and this estimate makes sense only apart from a numerical factor of order unity. This energy is liberated when a Cooper pair of protons at $k = 139$ space-time sheet drops to the magnetic flux tube of Earth's magnetic field (or some other sufficiently large space-time sheet). This energy is rather near to the threshold value about 55 meV of the membrane potential.

2. 21 micrometer radiation could also result when electrons at $k = 151$ space-time sheet drop to a large enough space-time sheet and liberate their zero point kinetic energy. Scaling argument gives for the zero point kinetic energy of electron at $k = 151$ space-time sheet the value $\Delta(e, 151) \simeq 57.5$ meV which is also quite near to the observed value. If electron is bound to wormhole with quantum numbers of $\overline{d}$ Coulombic binding energy changes the situation.

3. A possible explanation is as a radiation associated with the transition to high T_c super conducting phase. There are two sources of photons. Radiation could perhaps result from the de-excitations of wormhole BE condensate by photon emission. $\lambda = 20.5$ micrometers is precisely what one expects if the space-time sheet corresponds to $p \simeq 2^k$, $k = 173$ and assumes that excitation energies are given as multiples of $E_w(k) = 2\pi/L(k)$. This predicts excitation energy $E_w(173) \simeq 61.5$ meV. Unfortunately, this radiation should correspond to a sharp emission line and cannot explain the wide spectrum.

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` [L13].

5.3 General TGD Based View About Super-Conductivity

Today super-conductivity includes besides the traditional low temperature super-conductors many other non-orthodox ones [D54]. These unorthodox super-conductors carry various attributes such as cuprate, organic, dichalcogenide, heavy fermion, bismute oxide, ruthenate, antiferromagnetic and ferromagnetic. Mario Rabinowitz has proposed a simple phenomenological theory of super-fluidity and super-conductivity which helps non-specialist to get a rough quantitative overall view about super-conductivity [D54].

5.3.1 Basic Phenomenology Of Super-Conductivity

The following provides the first attempt by a non-professional to form an overall view about super-conductivity.

Basic phenomenology of super-conductivity

The transition to super-conductivity occurs at critical temperature T_c and involves a complete loss of electrical resistance. Super-conductors expel magnetic fields (Meissner effect) and when the external magnetic field exceeds a critical value H_c super-conductivity is lost either completely or partially. In the transition to super-conductivity specific heat has singularity. For long time magnetism and super-conductivity were regarded as mutually exclusive phenomena but the discovery of ferromagnetic super-conductors [D40, D17] has demonstrated that reality is much more subtle.

The BCS theory developed by Bardeen, Cooper, and Schrieffer in 1957 provides a satisfactory model for low T_c super-conductivity in terms of Cooper pairs. The interactions of electrons with the crystal lattice induce electron-electron interaction binding electrons to Cooper pairs at sufficiently low temperatures. The electrons of Cooper pair are at the top of Fermi sphere (otherwise they cannot interact to form bound states) and have opposite center of mass momenta and spins. The binding creates energy gap E_g determining the critical temperature T_c. The singularity of the specific heat in the transition to super-conductivity can be understood as being due to the loss of thermally excitable degrees of freedom at critical temperature so that heat capacity is reduced exponentially. BCS theory has been successful in explaining the properties of low temperature super conductors but the high temperature super-conductors discovered in 1986 and other non-orthodox superconductors discovered later remain a challenge for theorists.

The reasons why magnetic fields tend to destroy super-conductivity is easy to understand. Lorentz force induces opposite forces to the electrons of Cooper pair since the momenta are opposite. Magnetic field tends also to turn the spins in the same direction. The super-conductivity is destroyed in fields for which the interaction energy of magnetic moment of electron with field is of the same order of magnitude as gap energy $E_g \sim T_c$: $e\hbar H_c/2m \sim T_c$.

If spins are parallel, the situation changes since only Lorentz force tends to destroy the Cooper pair. In high T_c super-conductors this is indeed the case: electrons are in spin triplet state ($S = 1$) and the net orbital angular momentum of Cooper pair is $L = 2$. The fact that orbital state is not $L = 0$ state makes high T_c super-conductors much more fragile to the destructive effect of impurities than conventional super-conductors (due to the magnetic exchange force between electrons responsible for magnetism). Also the Cooper pairs of ^3He superfluid are in spin triplet state but have $S = 0$.

The observation that spin triplet Cooper pairs might be possible in ferro-magnets stimulates the question whether ferromagnetism and super-conductivity might tolerate each other after all, and the answer is affirmative [D17]. The article [D40] provides an enjoyable summary of experimental discoveries.

Basic parameters of super-conductors from universality?

Super conductors are characterized by certain basic parameters such as critical temperature T_c and critical magnetic field H_c, densities n_c and n of Cooper pairs and conduction electrons, gap energy E_g, correlation length ξ and magnetic penetration length λ. The super-conductors are highly complex systems and calculation of these parameters from BCS theory is either difficult or impossible.

It has been suggested [D54] that these parameters might be more or less universal so that they would not depend on the specific properties of the interaction responsible for the formation of Cooper pairs. The motivation comes from the fact that the properties of ordinary Bose-Einstein condensates do not depend on the details of interactions. This raises the hope that these parameters might be expressible in terms of some basic parameters such as T_c and the density of conduction electrons allowing to deduce Fermi energy E_F and Fermi momentum k_F if Fermi surface is sphere. In [D54] formulas for the basic parameters are indeed suggested based on this of argumentation assuming that Cooper pairs form a Bose-Einstein condensate.

1. The most important parameters are critical temperature T_c and critical magnetic field H_c in principle expressible in terms of gap energy. In [D54] the expression for T_c is deduced from the condition that the de Broglie wavelength λ must satisfy in supra phase the condition

$$\lambda \geq 2d = 2(\frac{n_c}{g})^{-1/D} \tag{5.3.1}$$

guaranteeing the quantum overlap of Cooper pairs. Here n_c is the density of Bose-Einstein condensate of Cooper pairs and g is the number of spin states and D the dimension of the condensate. This condition follows also from the requirement that the number of particles per energy level is larger than one (Bose-Einstein condensation).

Identifying this expression with the de Broglie wavelength $\lambda = \hbar/\sqrt{2mE}$ at thermal energy $E = (D/2)T_c$, where D is the number of degrees of freedom, one obtains

$$T_c \leq \frac{h^2}{4Dm}(\frac{n_c}{g})^{2/D} . \tag{5.3.2}$$

m denotes the effective mass of super current carrier and for electron it can be even 100 times the bare mass of electron. The reason is that the electron moves is somewhat like a person trying to move in a dense crowd of people, and is accompanied by a cloud of charge carriers increasing its effective inertia. In this equation one can consider the possibility that Planck constant is not the ordinary one. This obviously increases the critical temperature unless n_c is scaled down in same proportion in the phase transition to large $\hbar$ phase.

2. The density of n_c Cooper pairs can be estimated as the number of fermions in Fermi shell at E_F having width Δk deducible from kT_c. For $D = 3$-dimensional spherical Fermi surface one has

$$\begin{aligned} n_c &= \frac{1}{2}\frac{4\pi k_F^2 \Delta k}{\frac{4}{3}\pi k_F^3} n , \\ kT_c &= E_F - E(k_F - \Delta k) \simeq \frac{h^2 k_F \Delta k}{m} . \end{aligned} \tag{5.3.3}$$

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

$$n_c(D) = \frac{D}{2}\frac{T_c}{E_F} n(D) . \tag{5.3.4}$$

The dimensionless coefficient is expressible solely in terms of n and effective mass m. In [D54] it is demonstrated that the inequality 5.3.2 replaced with equality when combined with 5.3.4 gives a satisfactory fit for 16 super-conductors used as a sample.

Note that the Planck constant appearing in E_F and T_c in Eq. 5.3.4 must correspond to ordinary Planck constant $\hbar_0$. This implies that equations 5.3.2 and 5.3.4 are consistent within orders of magnitudes. For $D = 2$, which corresponds to high T_c superconductivity, the substitution of n_c from Eq. 5.3.4 to Eq. 5.3.2 gives a consistency condition from which n_c disappears completely. The condition reads as

$$n\lambda_F^2 = \pi = 4g .$$

Obviously the equation is not completely consistent.

3. The magnetic penetration length λ is expressible in terms of density n_c of Cooper pairs as

$$\lambda^{-2} = \frac{4\pi e^2 n_c}{m_e} . \tag{5.3.5}$$

The ratio $\kappa \equiv \frac{\lambda}{\xi}$ determines the type of the super conductor. For $\kappa < \frac{1}{\sqrt{2}}$ one has type I super conductor with defects having negative surface energy. For $\kappa \geq \frac{1}{\sqrt{2}}$ one has type II super conductor and defects have positive surface energy. Super-conductors of type I this results in complex stripe like flux patterns maximizing their area near criticality. The super-conductors of type II have $\kappa > 1/\sqrt{2}$ and the surface energy is positive so that the flux penetrates as flux quanta minimizing their area at lower critical value H_{c_1} of magnetic field and completely at higher critical value H_{c_2} of magnetic field. The flux quanta contain a core of size ξ carrying quantized magnetic flux.

4. Quantum coherence length ξ can be roughly interpreted as the size of the Cooper pair or as the size of the region where it is sensible to speak about the phase of wave function of Cooper pair. For larger separations the phases of wave functions are un-correlated. The values of ξ vary in the range $10^3 - 10^4$ Angstrom for low T_c super-conductors and in the range $5-20$ Angstrom for high T_c super-conductors (assuming that they correspond to ordinary $\hbar$!) the ratio of these coherence lengths varies in the range $[50-2000]$, with upper bound corresponding to $n_F = 2^{11}$ for $\hbar$. This would give range $1-2$ microns for the coherence lengths of high T_c super-conductors with lowest values of coherence lengths corresponding to the highest values of coherence lengths for low temperatures super conductors.

Uncertainty Principle $\delta E \delta t = \hbar/2$ using $\delta E = E_g \equiv 2\Delta$, $\delta t = \xi/v_F$, gives an order of magnitude estimate for ξ differing only by a numerical factor from the result of a rigorous calculation given by

$$\xi = \frac{4\hbar v_F}{E_g} . \tag{5.3.6}$$

E_g is apart from a numerical constant equal to T_c: $E_g = nT_c$. Using the expression for v_F and T_c in terms of the density of electrons, one can express also ξ in terms of density of electrons.

For instance, BCS theory predicts $n = 3.52$ for metallic super-conductors and $n = 8$ holds true for cuprates [D54]. For cuprates one obtains $\xi = 2n^{-1/3}$ [D54]. This expression can be criticized since cuprates are Mott insulators and it is not at all clear whether a description as Fermi gas makes sense. The fact that high T_c super-conductivity involves breakdown of anti-ferromagnetic order might justify the use of Fermi gas description for conducting holes resulting in the doping.

For large $\hbar$ the value of ξ would scale up dramatically if deduced theoretically from experimental data using this kind of expression. If the estimates for ξ are deduced from v_F and T_c purely calculationally as seems to be the case, the actual coherence lengths would be scaled up by a factor $\hbar/\hbar_0 = n_F$ if high T_c super-conductors correspond to large $\hbar$ phase. As also found that this would also allow to understand the high critical temperature.

5.3.2 Universality Of The Parameters In TGD Framework

Universality idea conforms with quantum criticality of TGD Universe. The possibility to express everything in terms of density of critical temperature coding for the dynamics of Cooper pair formation and the density charge carriers would make it also easy to understand how p-adic scalings and transitions to large $\hbar$ phase affect the basic parameters. The possible problem is that the replacement of inequality of Eq. 5.3.2 with equality need not be sensible for large $\hbar$ phases. It will be found that in many-sheeted space-time T_c does not directly correspond to the gap energy and the universality of the critical temperature follows from the p-adic length scale hypothesis.

The effect of p-adic scaling on the parameters of super-conductors

p-Adic fractality expresses as $n \propto 1/L^3(k)$ would allow to deduce the behavior of the various parameters as function of the p-adic length scale and naïve scaling laws would result. For instance, E_g and T_c would scale as $1/L^2(k)$ if one assumes that the density n of particles at larger space-time sheets scales p-adically as $1/L^3(k)$. The basic implication would be that the density of Cooper pairs and thus also T_c would be reduced very rapidly as a function of the p-adic length scale. Without thermal isolation between these space-time sheets and hight temperature space-time sheets there would not be much hopes about high T_c super-conductivity.

In the scaling of Planck constant basic length scales scale up and the overlap criterion for super-conductivity becomes easy to satisfy unless the density of electrons is reduced too dramatically. As found, also the critical temperature scales up so that there are excellent hopes of obtain high T_c super-conductor in this manner. The claimed short correlation lengths are not a problem since they are calculational quantities.

It is of interest to study the behavior of the various parameters in the transition to the possibly existing large $\hbar$ variant of super-conducting electrons. Also small scalings of $\hbar$ are possible and the considerations to follow generalize trivially to this case. Under what conditions the behavior of the various parameters in the transition to large $\hbar$ phase is dictated by simple scaling laws?

1. Scaling of T_c and E_g

T_c and E_g remain invariant if E_g corresponds to a purely classical interaction energy remaining invariant under the scaling of $\hbar$. This is not the case for BCS super-conductors for which the gap energy E_g has the following expression.

$$\begin{aligned} E_g &= \hbar\omega_c exp(-1/X) \ , \\ X &= n(E_F)U_0 = \frac{3}{2}N(E_F)\frac{U_0}{E_F} \ , \\ n(E_F) &= \frac{3}{2}\frac{N(E_F)}{E_F} \ . \\ \omega_c &= \omega_D = (6\pi^2)^{1/3}c_s n_n^{1/3} \ . \end{aligned} \tag{5.3.7}$$

Here ω_c is the width of energy region near E_F for which "phonon" exchange interaction is effective. n_n denotes the density of nuclei and c_s denotes sound velocity.

$N(E_F)$ is the total number of electrons at the super-conducting space-time sheet. U_0 would be the parameter characterizing the interaction strength of of electrons of Cooper pair and should not depend on $\hbar$. For a structure of size $L \sim 1$ μ m one would have $X \sim n_a 10^{12}\frac{U_0}{E_F}$, n_a being the number of exotic electrons per atom, so that rather weak interaction energy U_0 can give rise to $E_g \sim \omega_c$.

The expression of ω_c reduces to Debye frequency ω_D in BCS theory of ordinary super conductivity. If c_s is proportional to thermal velocity $\sqrt{T_c/m}$ at criticality and if n_n remains invariant in the scaling of $\hbar$, Debye energy scales up as $\hbar$. This can imply that $E_g > E_F$ condition making scaling non-sensible unless one has $E_g \ll E_F$ holding true for low T_c super-conductors. This kind of situation would *not* require large $\hbar$ phase for electrons. What would be needed that nuclei and phonon space-time sheets correspond to large $\hbar$ phase.

What one can hope is that E_g scales as $\hbar$ so that high T_c superconductor would result and the scaled up T_c would be above room temperature for $T_c > .15$ K. If electron is in ordinary phase X is automatically invariant in the scaling of $\hbar$. If not, the invariance reduces to the invariance of U_0 and E_F under the scaling of $\hbar$. If n scales like $1/\hbar^D$, E_F and thus X remain invariant. U_0 as a simplified parameterization for the interaction potential expressible as a tree level Feynman diagram is expected to be in a good approximation independent of $\hbar$.

It will be found that in high T_c super-conductors, which seem to be quantum critical, a high T_c variant of phonon mediated superconductivity and exotic superconductivity could be competing. This would suggest that the phonon mediated superconductivity corresponds to a large $\hbar$ phase for nuclei scaling ω_D and T_c by a factor $r = \hbar/\hbar_0$.

Since the total number $N(E_F)$ of electrons at larger space-time sheet behaves as $N(E_F) \propto E_F^{D/2}$, where D is the effective dimension of the system, the quantity $1/X \propto E_F/n(E_F)$ appearing in the expressions of the gap energy behaves as $1/X \propto E_F^{-D/2+1}$. This means that at the limit of vanishing electron density $D = 3$ gap energy goes exponentially to zero, for $D = 2$ it is constant, and for $D = 1$ it goes zero at the limit of small electron number so that the formula for gap energy reduces to $E_g \simeq \omega_c$. These observations suggests that the super-conductivity in question should be 2- or 1-dimensional phenomenon as in case of magnetic walls and flux tubes.

2. Scaling of ξ and λ

If n_c for high T_c super-conductor scales as $1/\hbar^D$ one would have $\lambda \propto \hbar^{D/2}$. High T_c property however suggests that the scaling is weaker. ξ would scale as $\hbar$ for given v_F and T_c. For $D = 2$

case the this would suggest that high T_c super-conductors are of type I rather than type II as they would be for ordinary $\hbar$. This conforms with the quantum criticality which would be counterpart of critical behavior of super-conductors of type I in nearly critical magnetic field.

3. Scaling of H_c and B

The critical magnetization is given by

$$H_c(T) = \frac{\Phi_0}{\sqrt{8}\pi\xi(T)\lambda(T)} \ , \tag{5.3.8}$$

where Φ_0 is the flux quantum of magnetic field proportional to $\hbar$. For $D = 2$ and $n_c \propto \hbar^{-2}$ $H_c(T)$ would not depend on the value of $\hbar$. For the more physical dependence $n_c \propto \hbar^{-2+\epsilon}$ one would have $H_c(T) \propto \hbar^{-\epsilon}$. Hence the strength of the critical magnetization would be reduced by a factor $2^{-11\epsilon}$ in the transition to the large $\hbar$ phase with $n_F = 2^{-11}$.

Magnetic flux quantization condition is replaced by

$$\int 2eBdS = n\hbar 2\pi \ . \tag{5.3.9}$$

B denotes the magnetic field inside super-conductor different from its value outside the super-conductor. By the quantization of flux for the non-super-conducting core of radius ξ in the case of super-conductors of type II $eB = \hbar/\xi^2$ holds true so that B would become very strong since the thickness of flux tube would remain unchanged in the scaling.

5.3.3 Quantum Criticality And Super-Conductivity

The notion of quantum criticality has been already discussed in introduction. An interesting prediction of the quantum criticality of entire Universe also gives naturally rise to a hierarchy of macroscopic quantum phases since the quantum fluctuations at criticality at a given level can give rise to higher level macroscopic quantum phases at the next level. A metaphor for this is a fractal cusp catastrophe for which the lines corresponding to the boundaries of cusp region reveal new cusp catastrophes corresponding to quantum critical systems characterized by an increasing length scale of quantum fluctuations.

Dark matter hierarchy could correspond to this kind of hierarchy of phases and long ranged quantum slow fluctuations would correspond to space-time sheets with increasing values of $\hbar$ and size. Evolution as the emergence of modules from which higher structures serving as modules at the next level would correspond to this hierarchy. Mandelbrot fractal with inversion analogous to a transformation permuting the interior and exterior of sphere with zooming revealing new worlds in Mandelbrot fractal replaced with its inverse would be a good metaphor for what quantum criticality would mean in TGD framework.

How the quantum criticality of superconductors relates to TGD quantum criticality

There is empirical support that super-conductivity in high T_c super-conductors and ferromagnetic systems [D40, D28] is made possible by quantum criticality [D58]. In the experimental situation quantum criticality means that at sufficiently low temperatures quantum rather than thermal fluctuations are able to induce phase transitions. Quantum criticality manifests itself as fractality and simple scaling laws for various physical observables like resistance in a finite temperature range and also above the critical temperature. This distinguishes sharply between quantum critical super conductivity from BCS type super-conductivity. Quantum critical super-conductivity also exists in a finite temperature range and involves the competition between two phases.

The absolute quantum criticality of the TGD Universe maps to the quantum criticality of subsystems, which is broken by finite temperature effects bringing dissipation and freezing of quantum fluctuations above length and time scales determined by the temperature so that scaling laws hold true only in a finite temperature range.

Reader has probably already asked what quantum criticality precisely means. What are the phases which compete? An interesting hypothesis is that quantum criticality actually corresponds to criticality with respect to the phase transition changing the value of Planck constant so that the competing phases would correspond to different values of $\hbar$. In the case of high T_c super-conductors (anti-ferromagnets) the fluctuations can be assigned to the magnetic flux tubes of the dipole field patterns generated by rows of holes with same spin direction assignable to the stripes. Below T_c fluctuations induce reconnections of the flux tubes and a formation of very long flux tubes and make possible for the supra currents to flow in long length scales below T_c. Percolation type phenomenon is in question. The fluctuations of the flux tubes below $T_{c1} > T_c$ induce transversal phonons generating the energy gap for $S = 1$ Cooper pairs. $S = 0$ Cooper pairs are predicted to stabilize below T_c.

Scaling up of de Broglie wave lengths and criterion for quantum overlap

Compton lengths and de Broglie wavelengths are scaled up by an integer n, whose preferred values correspond to $n_F = 2^k \prod_s F_s$, where $F_s = 2^{2^s} + 1$ are distinct Fermat primes. In particular, $n_F = 2^{k11}$ seem to be favored in living matter. The scaling up means that the overlap condition $\lambda \geq 2d$ for the formation of Bose-Einstein condensate can be satisfied and the formation of Cooper pairs becomes possible. Thus a hierarchy of large $\hbar$ super-conductivities would be associated with to the dark variants of ordinary particles having essentially same masses as the ordinary particles.

Unless one assumes fractionization, the invariance of $E_F \propto \hbar_{eff}^2 n^{2/3}$ in $\hbar$ increasing transition would require that the density of Cooper pairs in large $\hbar$ phase is scaled down by an appropriate factor. This means that supra current intensities, which are certainly measurable quantities, are also scaled down. Of course, it could happen that E_F is scaled up and this would conform with the scaling of the gap energy.

Quantum critical super-conductors in TGD framework

For quantum critical super-conductivity in heavy fermions systems, a small variation of pressure near quantum criticality can destroy ferromagnetic (anti-ferromagnetic) order so that Curie (Neel) temperature goes to zero. The prevailing spin fluctuation theory [D14] assumes that these transitions are induced by long ranged and slow spin fluctuations at critical pressure P_c. These fluctuations make and break Cooper pairs so that the idea of super-conductivity restricted around critical point is indeed conceivable.

Heavy fermion systems, such as cerium-indium alloy $CeIn_3$ are very sensitive to pressures and a tiny variation of density can drastically modify the low temperature properties of the systems. Also other systems of this kind, such as $CeCu_2Ge_2$, $CeIn_3$, $CePd_2Si_2$ are known [D40, D17]. In these cases super-conductivity appears around anti-ferromagnetic quantum critical point.

The last experimental breakthrough in quantum critical super-conductivity was made in Grenoble [D28]. URhGe alloy becomes super-conducting at $T_c = .280$ K, loses its super-conductivity at $H_c = 2$ Tesla, and becomes again super-conducting at $H_c = 12$ Tesla and loses its super-conductivity again at $H = 13$ Tesla. The interpretation is in terms of a phase transition changing the magnetic order inducing the long range spin fluctuations.

TGD based models of atomic nucleus [K97] and condensed matter [K38] assume that weak gauge bosons with Compton length of order atomic radius play an essential role in the nuclear and condensed matter physics. The assumption that condensed matter nuclei possess anomalous weak charges explains the repulsive core of potential in van der Waals equation and the very low compressibility of condensed matter phase as well as various anomalous properties of water phase, provide a mechanism of cold fusion and sono-fusion, etc. [K38, K36]. The pressure sensitivity of these systems would directly reflect the physics of exotic quarks and electro-weak gauge bosons. A possible mechanism behind the phase transition to super-conductivity could be the scaling up of the sizes of the space-time sheets of nuclei.

Also the electrons of Cooper pair (and only these) could make a transition to large $\hbar$ phase. This transition would induce quantum overlap having geometric overlap as a space-time correlate. The formation of flux tubes between neighboring atoms would be part of the mechanism. For instance, the criticality condition $4n^2\alpha = 1$ for BE condensate of n Cooper pairs would give $n = 6$ for the size of a higher level quantum unit possibly formed formed from Cooper pairs. If one does not assume invariance of energies obtained by fractionization of principal quantum number, this transition has dramatic effects on the spectrum of atomic binding energies scaling as $1/\hbar^2$

and practically universal spectrum of atomic energies would result [K36] not depending much on nuclear charge. It seems that this prediction is non-physical.

Quantum critical super-conductors resemble superconductors of type I with $\lambda \ll \xi$ for which defects near thermodynamical criticality are complex structures looking locally like stripes of thickness λ. These structures are however dynamical in super-conducting phase. Quite generally, long range quantum fluctuations due to the presence of two competing phases would manifest as complex dynamical structures consisting of stripes and their boundaries. These patterns are dynamical rather than static as in the case of ordinary spin glass phase so that quantum spin glass or 4-D spin glass is a more appropriate term. The breaking of classical non-determinism for vacuum extremals indeed makes possible space-time correlates for quantum non-determinism and this makes TGD Universe a 4-dimensional quantum spin glass.

Could quantum criticality make possible new kinds of high T_c super-conductors?

The transition to large $\hbar = r\hbar_0$ phase increases various length scales by r and makes possible long range correlations even at high temperatures. Hence the question is whether large $\hbar$ phase could correspond to ordinary high T_c super-conductivity. If this were the case in the case of ordinary high T_c super-conductors, the actual value of coherence length ξ would vary in the range $5-20$ Angstrom scaled up by a factor r. For effectively D-dimensional super-conductor The density of Cooper pairs would be scaled down by an immensely small factor $1/r^D$ from its value deduced from Fermi energy.

Large $\hbar$ phase for some nuclei might be involved and make possible large space-time sheets of size at least of order of ξ at which conduction electrons forming Cooper pairs would topologically condense like quarks around hadronic space-time sheets (in [K38] a model of water as a partially dark matter with one fourth of hydrogen ions in large $\hbar$ phase is developed).

Consider for a moment the science fictive possibility that super conducting electrons for some quantum critical super-conductors to be discovered or already discovered correspond to large $\hbar$ phase with $\hbar = r\hbar_0$ keeping in mind that this affects only quantum corrections in perturbative approach but not the lowest order classical predictions of quantum theory. For $r \simeq n2^{k11}$ with $(n,k) = (1,1)$ the size of magnetic body would be $L(149) = 5$ nm, the thickness of the lipid layer of cell membrane. For $(n,k) = (1,2)$ the size would be $L(171) = 10$ μm, cell size. If the density of Cooper pairs is of same order of magnitude as in case of ordinary super conductors, the critical temperature is scaled up by 2^{k11}. Already for $k = 1$ the critical temperature of 1 K would be scaled up to $4n^2 \times 10^6$ K if n_c is not changed. This assumption is not consistent with the assumption that Fermi energy remains non-relativistic. For $n = 1$ $T_c = 400$ K would be achieved for $n_c \rightarrow 10^{-6}n_c$, which looks rather reasonable since Fermi energy transforms as $E_F \rightarrow 8 \times 10^3 E_F$ and remains non-relativistic. H_c would scale down as $1/\hbar$ and for $H_c = .1$ Tesla the scaled down critical field would be $H_c = .5 \times 10^{-4}$ Tesla, which corresponds to the nominal value of the Earth's magnetic field.

Quantum critical super-conductors become especially interesting if one accepts the identification of living matter as ordinary matter quantum controlled by macroscopically quantum coherent dark matter. One of the basic hypothesis of TGD inspired theory of living matter is that the magnetic flux tubes of the Earth's magnetic field carry a super-conducting phase and the spin triplet Cooper pairs of electrons in large $\hbar$ phase might realize this dream. That the value of Earth's magnetic field is near to its critical value could have also biological implications.

5.3.4 Space-Time Description Of The Mechanisms OfSuper-Conductivity

The application of ideas about dark matter to nuclear physics and condensed matter suggests that dark color and weak forces should be an essential element of the chemistry and condensed matter physics. The continual discovery of new super-conductors, in particular of quantum critical superconductors, suggests that super-conductivity is not well understood. Hence super-conductivity provides an obvious test for these ideas. In particular, the idea that wormhole contacts regarded as parton pairs living at two space-time sheets simultaneously, provides an attractive universal mechanism for the formation of Cooper pairs and is not so far-fetched as it might sound first.

Leading questions

It is good to begin with a series of leading questions. The first group of questions is inspired by experimental facts about super-conductors combined with TGD context.

1. The work of Rabinowitch [D54] suggests that that the basic parameters of super-conductors might be rather universal and depend on T_c and conduction electron density only and be to a high degree independent of the mechanism of super-conductivity. This is in a sharp contrast to the complexity of even BCS model with its somewhat misty description of the phonon exchange mechanism.
   Questions: Could there exist a simple universal description of various kinds of super-conductivities?

2. The new super-conductors possess relatively complex chemistry and lattice structure.
   Questions: Could it be that complex chemistry and lattice structure makes possible something very simple describable in terms of quantum criticality. Could it be that the transversal oscillations magnetic flux tubes allow to understand the formation of Cooper pairs at T_{c1} and their reconnections generating very long flux tubes the emergence of supra currents at T_c?

3. The effective masses of electrons in ferromagnetic super-conductors are in the range of 10-100 electron masses [D40] and this forces to question the idea that ordinary Cooper pairs are current carriers.
   Questions: Can one consider the possibility that the p-adic length scale of say electron can vary so that the actual mass of electron could be large in condensed matter systems? For quarks and neutrinos this seems to be the case [K56, K66]. Could it be that the Gaussian Mersennes $(1+i)^k-1$, $k = 151, 157, 163, 167$ spanning the p-adic lengthscale range 10 nm-2.5 μm very relevant from the point of view of biology correspond to p-adic length especially relevant for super-conductivity?

Second group of questions is inspired by quantum classical correspondence.

1. Quantum classical correspondence in its strongest form requires that bound state formation involves the generation of flux tubes between bound particles. The weaker form of the principle requires that the particles are topologically condensed at same space-time sheet. In the case of Cooper pairs in ordinary superconductors the length of join along boundaries bonds between electrons should be of order $10^3 - 10^4$ Angstroms. This looks rather strange and it seems that the latter option is more sensible.
   Questions: Could quantum classical correspondence help to identify the mechanism giving rise to Cooper pairs?

2. Quantum classical correspondence forces to ask for the space-time correlates for the existing quantum description of phonons.
   Questions: Can one assign space-time sheets with phonons or should one identify them as oscillations of say space-time sheets at which atoms are condensed? Or should the microscopic description of phonons in atomic length scales rely on the oscillations of wormhole contacts connecting atomic space-time sheets to these larger space-time sheets? The identification of phonons as wormhole contacts would be completely analogous to the similar identification of gauge bosons except that phonons would appear at higher levels of the hierarchy of space-time sheets and would be emergent in this sense. As a matter fact, even gauge bosons as pairs of fermion and anti-fermion are emergent structures in TGD framework and this plays fundamental role in the construction of QFT limit of TGD in which bosonic part of action is generated radiatively so that all coupling constants follow as predictions [**?**]. Could Bose-Einstein condensates of wormhole contacts be relevant for the description of super-conductors or more general macroscopic quantum phases?

The third group of questions is inspired by the new physics predicted or by TGD.

1. TGD predicts a hierarchy of macroscopic quantum phases with large Planck constant.
   Questions: Could large values of Planck constant make possible exotic electronic super-conductivities? Could even nuclei possess large $\hbar$ (super-fluidity)?

2. TGD predicts that classical color force and its quantal counterpart are present in all length scales.
Questions: Could color force, say color magnetic force which play some role in the formation of Cooper pair. The simplest model of pair is as a space-time sheet with size of order ξ so that the electrons could be "outside" the background space-time. Could the Coulomb interaction energy of electrons with positively charged wormhole throats carrying parton numbers and feeding em gauge flux to the large space-time sheet be responsible for the gap energy? Could wormhole throats carry also quark quantum numbers. In the case of single electron condensed to single space-time sheet the em flux could be indeed fed by a pair of $u\overline{u}$ and $\overline{d}d$ type wormhole contacts to a larger space-time sheet. Could the wormhole contacts have a net color? Could the electron space-time sheets of the Cooper pair be connected by long color flux tubes to give color singlets so that dark color force would be ultimately responsible for the stability of Cooper pair?

3. Suppose that one takes seriously the ideas about the possibility of dark weak interactions with the Compton scale of weak bosons scaled up to say atomic length scale so that weak bosons are effectively massless below this length scale [K38].
Questions: Could the dark weak length scale which is of order atomic size replace lattice constant in the expression of sound velocity? What is the space-time correlate for sound velocity?

Photon massivation, coherent states of Cooper pairs, and wormhole contacts

The existence of wormhole contacts is one of the most stunning predictions of TGD. First I realized that wormhole contacts can be regarded as parton-antiparton pairs with parton and antiparton assignable to the light-like causal horizons accompanying wormhole contacts. Then came the idea that Higgs particle could be identified as a wormhole contact. It was soon followed by the identification all bosonic states as wormhole contacts [K56]. Finally I understood that this applies also to their super-symmetric partners, which can be also fermion [?]. Fermions and their super-partners would in turn correspond to wormhole throats resulting in the topological condensation of small deformations of CP_2 type vacuum extremals with Euclidian signature of metric to the background space-time sheet. This framework opens the doors for more concrete models of also super-conductivity involving the effective massivation of photons as one important aspect in the case of ordinary super-conductors.

There are two types of wormhole contacts. Those of first type correspond to elementary bosons. Wormhole contacts of second kind are generated in the topological condensation of space-time sheets carrying matter and form a hierarchy. Classical radiation fields realized in TGD framework as oscillations of space-time sheets would generate wormhole contacts as the oscillating space-time sheet develops contacts with parallel space-time sheets (recall that the distance between space-time sheets is of order CP_2 size). This realizes the correspondence between fields and quanta geometrically. Phonons could also correspond to wormhole contacts of this kind since they mediate acoustic oscillations between space-time sheets and the description of the phonon mediated interaction between electrons in terms of wormhole contacts might be useful also in the case of super-conductivity. Bose-Einstein condensates of wormhole contacts might be highly relevant for the formation of macroscopic quantum phases. The formation of a coherent state of wormhole contacts would be the counterpart for the vacuum expectation value of Higgs.

The notions of coherent states of Cooper pairs and of charged Higgs challenge the conservation of electromagnetic charge. The following argument however suggests that coherent states of wormhole contacts form only a part of the description of ordinary super-conductivity. The basic observation is that wormhole contacts with vanishing fermion number define space-time correlates for Higgs type particle with fermion and anti-fermion numbers at light-like throats of the contact.

The ideas that a genuine Higgs type photon massivation is involved with super-conductivity and that coherent states of Cooper pairs really make sense are somewhat questionable since the conservation of charge and fermion number is lost for coherent states. A further questionable feature is that a quantum superposition of many-particle states with widely different masses would be in question. These interpretational problems can be resolved elegantly in zero energy ontology [K28] in which the total conserved quantum numbers of quantum state are vanishing. In this picture the energy, fermion number, and total charge of any positive energy state are compensated by opposite quantum numbers of the negative energy state in geometric future. This makes possible to speak about superpositions of Cooper pairs and charged Higgs bosons separately in positive energy sector.

If this picture is taken seriously, super-conductivity can be seen as providing a direct support for both the hierarchy of scaled variants of standard model physics and for the zero energy ontology.

Space-time correlate for quantum critical superconductivity

The explicit model for high T_c super-conductivity relies on quantum criticality involving long ranged quantum fluctuations inducing reconnection of flux tubes of local (color) magnetic fields associated with parallel spins associated with stripes to form long flux tubes serving as wires along which Cooper pairs flow. Essentially [D5] [D5] type phenomenon would be in question. The role of the doping by holes is to make room for Cooper pairs to propagate by the reconnection mechanism: otherwise Fermi statistics would prevent the propagation. Too much doping reduces the number of current carriers, too little doping leaves too little room so that there exists some optimal doping. In the case of high T_c super-conductors quantum criticality corresponds to a quite wide temperature range, which provides support for the quantum criticality of TGD Universe. The probability $p(T)$ for the formation of reconnections is what matters and exceeds the critical value at T_c.

5.3.5 Super-Conductivity At Magnetic Flux Tubes

Super-conductivity at the magnetic flux tubes of magnetic flux quanta is one the basic hypothesis of the TGD based model of living matter. There is also evidence for magnetically mediated super-conductivity in extremely pure samples [D29]. The magnetic coupling was only observed at lattice densities close to the critical density at which long-range magnetic order is suppressed. Quantum criticality that long flux tubes serve as pathways along which Cooper pairs can propagate. In anti-ferromagnetic phase these pathways are short-circuited to closed flux tubes of local magnetic fields.

Almost the same model as in the case of high T_c and quantum critical super-conductivity applies to the magnetic flux tubes. Now the flux quantum contains BE condensate of exotic Cooper pairs interacting with wormhole contacts feeding the gauge flux of Cooper pairs from the magnetic flux quantum to a larger space-time sheet. The interaction of spin 1 Cooper pairs with the magnetic field of flux quantum orients their spins in the same direction. Large value of $\hbar$ guarantees thermal stability even in the case that different space-time sheets are not thermally isolated.

The understanding of gap energy is not obvious. The transversal oscillations of magnetic flux tubes generated by spin flips of electrons define the most plausible candidate for the counterpart of phonons. In this framework phonon like states identified as wormhole contacts would be created by the oscillations of flux tubes and would be a secondary phenomenon.

Large values of $\hbar$ allow to consider not only the Cooper pairs of electrons but also of protons and fermionic ions. Since the critical temperature for the formation of Cooper pairs is inversely proportional to the mass of the charge carrier, the replacement of electron with proton or ion would require a scaling of $\hbar$. If T_{c1} is proportional to $\hbar^2$, this requires scaling by $(m_p/m_e)^{1/2}$. For $T_{c1} \propto \hbar$ scaling by $m_p/m_e \simeq 2^{11}$ is required. This inspired idea that powers of 2^{11} could define favored values of $\hbar/\hbar_0$. This hypothesis is however rather ad hoc and turned out to be too restrictive.

Besides Cooper pairs also Bose-Einstein condensates of bosonic ions are possible in large $\hbar$ phase and would give rise to super-conductivity. TGD inspired nuclear physics predicts the existence of exotic bosonic counterparts of fermionic nuclei with given (A, Z) [L3], [L3].

Superconductors at the flux quanta of the Earth's magnetic field

Magnetic flux tubes and magnetic walls are the most natural candidates for super-conducting structures with spin triplet Cooper pairs. Indeed, experimental evidence relating to the interaction of ELF em radiation with living matter suggests that bio-super-conductors are effectively 1- or 2-dimensional. $D \leq 2$-dimensionality is guaranteed by the presence of the flux tubes or flux walls of, say, the magnetic field of Earth in which charge carries form bound states and the system is equivalent with a harmonic oscillator in transversal degrees of freedom.

The effect of Earth's magnetic field is completely negligible at the atomic space-time sheets and cannot make super conductor 1-dimensional. At cellular sized space-time sheets magnetic field makes possible transversal the confinement of the electron Cooper pairs in harmonic oscillator states but does not explain energy gap which should be at the top of 1-D Fermi surface. The critical temperature extremely low for ordinary value of $\hbar$ and either thermal isolation between space-time sheets or large value of $\hbar$ can save the situation.

An essential element of the picture is that topological quantization of the magnetic flux tubes occurs. In fact, the flux tubes of Earth's magnetic field have thickness of order cell size from the quantization of magnetic flux. The observations about the effects of ELF em fields on bio-matter [J25] suggest that similar mechanism is at work also for ions and in fact give very strong support for bio-super conductivity based on the proposed mechanism.

Energy gaps for superconducting magnetic flux tubes and walls

Besides the formation of Cooper pairs also the Bose-Einstein condensation of charge carriers to the ground state is needed in order to have a supra current. The stability of Bose-Einstein condensate requires an energy gap $E_{g,BE}$ which must be larger than the temperature at the magnetic flux tube.

Several energies must be considered in order to understand $E_{g,BE}$.

1. The Coulombic binding energy of Cooper pairs with the wormhole contacts feeding the em flux from magnetic flux tube to a larger space-time sheet defines an energy gap which is expected to be of order $E_{g,BE} = \alpha/L(k)$ giving $E_g \sim 10^{-3}$ eV for $L(167) = 2.5$ μm giving a rough estimate for the thickness of the magnetic flux tube of the Earth's magnetic field $B = .5 \times 10^{-4}$ Tesla.

2. In longitudinal degrees of freedom of the flux tube Cooper pairs can be described as particles in a one-dimensional box and the gap is characterized by the length L of the magnetic flux tube and the value of $\hbar$. In longitudinal degrees of freedom the difference between $n = 2$ and $n = 1$ states is given by $E_0(k_2) = 3h^2/4m_eL^2(k_2)$. Translational energy gap $E_g = 3E_0(k_2) = 3h^2/4m_eL^2(k_2)$ is smaller than the effective energy gap $E_0(k_1) - E_0(k_2) = h^2/4m_eL^2(k_1) - h^2/4m_eL^2(k_2)$ for $k_1 > k_2+2$ and identical with it for $k_1 = k_2+2$. For $L(k_2 = 151)$ the zero point kinetic energy is given by $E_0(151) = 20.8$ meV so that $E_{g,BE}$ corresponds roughly to a temperature of 180 K. For magnetic walls the corresponding temperature would be scaled by a factor of two to 360 K and is above room temperature.

3. Second troublesome energy gap relates to the interaction energy with the magnetic field. The magnetic interaction energy E_m of Cooper pair with the magnetic field consists of cyclotron term $E_c = n\hbar eB/m_e$ and spin-interaction term which is present only for spin triplet case and is given by $E_s = \pm\hbar eB/m_e$ depending on the orientation of the net spin with magnetic field. In the magnetic field $B_{end} = 2B_E/5 = .2$ Gauss ($B_E = .5$ Gauss is the nominal value of the Earth's magnetic field) explaining the effects of ELF em fields on vertebrate brain, this energy scale is $\sim 10^{-9}$ eV for $\hbar_0$ and $\sim 1.6 \times 10^{-5}$ eV for $\hbar = 2^{14} \times \hbar_0$.

The smallness of translational and magnetic energy gaps in the case of Cooper pairs at Earth's magnetic field could be seen as a serious obstacle.

1. Thermal isolation between different space-time sheets provides one possible resolution of the problem. The stability of the Bose-Einstein condensation is guaranteed by the thermal isolation of space-time if the temperature at the magnetic flux tube is below E_m. This can be achieved in all length scales if the temperature scales as the zero point kinetic energy in transversal degrees of freedom since it scales in the same manner as magnetic interaction energy.

2. The transition to large $\hbar$ phase could provide a more elegant way out of the difficulty. The criterion for a sequence of transitions to a large $\hbar$ phase could be easily satisfied if there is a large number of charge Cooper pairs at the magnetic flux tube. Kinetic energy gap remains invariant if the length of the flux tube scales as $\hbar$. If the magnetic flux is quantized as a multiple of $\hbar$ and flux tube thickness scales as $\hbar^2$, B must scale as $1/\hbar$ so that also

magnetic energy remains invariant under the scaling. This would allow to have stability without assuming low temperature at magnetic flux tubes.

5.4 TGD Based Model For High T_c Super Conductors

High T_c superconductors are quantum critical and involve in an essential magnetic structures, they provide an attractive application of the general vision for the model of super-conductivity based on magnetic flux tubes.

5.4.1 Some Properties Of High T_c Super Conductors

Quite generally, high T_c super-conductors are cuprates with CuO layers carrying the supra current. The highest known critical temperature for high T_c superconductors is 164 K and is achieved under huge pressure of 3.1×10^5 atm for LaBaCuO. High T_c super-conductors are known to be super conductors of type II.

This is however a theoretical deduction following from the assumption that the value of Planck constant is ordinary. For $\hbar = 2^{14}\hbar_0$ (say) ξ would be scaled up accordingly and type I super-conductor would be in question. These super-conductors are characterized by very complex patterns of penetrating magnetic field near criticality since the surface area of the magnetic defects is maximized. For high T_c super-conductors the ferromagnetic phase could be regarded as an analogous to defect and would indeed have very complex structure. Since quantum criticality would be in question the stripe structure would fluctuate with time too in accordance with 4-D spin glass character.

The mechanism of high T_c super conductivity is still poorly understood [D45, D47].

1. It is agreed that electronic Cooper pairs are charge carriers. It is widely accepted that electrons are in relative d-wave state rather than in s-wave (see [D39] and the references mentioned in [D45]). Cooper pairs are believed to be in spin triplet state and electrons combine to form $L = 2$ angular momentum state. The usual phonon exchange mechanism does not generate the attractive interaction between the members of the Cooper pair having spin. There is also a considerable evidence for BCS type Cooper pairs and two kinds of Cooper pairs could be present.

2. High T_c super conductors have spin glass like character [D43]. High T_c superconductors have anomalous properties also above T_c suggesting quantum criticality implying fractal scaling of various observable quantities such as resistivity. At high temperatures cuprates are anti-ferromagnets and Mott insulators meaning freezing of the electrons. Superconductivity and conductivity are believed to occur along dynamical stripes which are antiferromagnetic defects.

3. These findings encourage to consider the interpretation in terms of quantum criticality in which some new form of super conductivity which is not based on quasiparticles is involved. This super-conductivity would be assignable with the quantum fluctuations destroying antiferromagnetic order and replacing it with magnetically disordered phase possibly allowing phonon induced super-conductivity.

4. The doping of the super-conductor with electron holes is essential for high T_c superconductivity, and there is a critical doping fraction $p = .14$ at which T_c is highest. The interpretation is that holes make possible for the Cooper pairs to propagate. There is considerable evidence that holes gather on one-dimensional stripes with thickness of order few atom sizes and lengths in the range 1-10 nm [D47], which are fluctuating in time scale of 10^{-12} seconds. These stripes are also present in non-superconducting state but in this case they do not fluctuate appreciably. The most plausible TGD based interpretation is in terms of fluctuations of magnetic flux tubes allowing for the formation of long connected flux tubes making super-conductivity possible. The fact that the fluctuations would be oscillations analogous to acoustic wave and might explain the BCS type aspects of high T_c super-conductivity.

5. T_c is inversely proportional to the distance L between the stripes. A possible interpretation would be that full super-conductivity requires de-localization of electrons also with respect to stripes so that T_c would be proportional to the hopping probability of electron between neighboring stripes expected to be proportional to $1/L$ [D47].

From free fermion gas to Fermi liquids to quantum critical systems

The article of Jan Zaanen [D46] gives an excellent non-technical discussion of various features of high T_c super-conductors distinguishing them from BCS super-conductors. After having constructed a color flux tube model of Cooper pairs I found it especially amusing to learn that the analogy of high T_c super-conductivity as a quantum critical phenomenon involving formation of dynamical stripes to QCD in the vicinity of the transition to the confined phase leading to the generation of string like hadronic objects was emphasized also by Zaanen.

BCS super-conductor behaves in a good approximation like quantum gas of non-interacting electrons. This approximation works well for long ranged interactions and the reason is Fermi statistics plus the fact that Fermi energy is much larger than Coulomb interaction energy at atomic length scales.

For strongly interacting fermions the description as Fermi liquid (a notion introduced by Landau) has been dominating phenomenological approach. ^{3}He provides a basic example of Fermi liquid and already here a paradox is encountered since low temperature collective physics is that of Fermi gas without interactions with effective masses of atoms about 6 times heavier than those of real atoms whereas short distance physics is that of a classical fluid at high temperatures meaning a highly correlated collective behavior.

It should be noticed that many-sheeted space-time provides a possible explanation of the paradox. Space-time sheets containing join along boundaries blocks of ^3He atoms behave like gas whereas the ^3He atoms inside these blocks form a liquid. An interesting question is whether the ^3He atoms combine to form larger units with same spin as ^3He atom or whether the increase of effective mass by a factor of order six means that $\hbar$ as a unit of spin is increased by this factor forcing the basic units to consist of Bose-Einstein condensate of 3 Cooper pairs.

High T_c super conductors are neither Fermi gases nor Fermi liquids. Cuprate superconductors correspond at high temperatures to doped Mott insulators for which Coulomb interactions dominate meaning that electrons are localized and frozen. Electron spin can however move and the system can be regarded as an anti-ferromagnet. CuO planes are separated by highly oxidic layers and become super-conducting when doped. The charge transfer between the two kinds of layers is what controls the degree of doping. Doping induces somehow a de-localization of charge carriers accompanied by a local melting of anti-ferromagnet.

Collective behavior emerges for high enough doping. Highest T_c results with 15 per cent doping by holes. Current flows along electron stripes. Stripes themselves are dynamical and this is essential for both conductivity and superconductivity. For completely static stripes superconductivity disappears and quasi-insulating electron crystal results.

Dynamical stripes appear in mesoscopic time and length scales corresponding to 1-10 nm length scale and picosecond time scale. The stripes are in a well-defined sense dual to the magnetized stripe like structures in type I super-conductor near criticality, which suggests analog of type I super-conductivity. The stripes are anti-ferromagnetic defects at which neighboring spins fail to be antiparallel. It has been found that stripes are a very general phenomenon appearing in insulators, metals, and super-conducting compounds [D16].

Quantum criticality is present also above T_c

Also the physics of Mott insulators above T_c reflects quantum criticality. Typically scaling laws hold true for observables. In particular, resistivity increases linearly rather than transforming from T^2 behavior to constant as would be implied by quasi-particles as current carriers. The appearance of so called pseudo-gap [D52] at $T_{c1} > T_c$ conforms with this interpretation. In particular, the pseudo-gap is non-vanishing already at T_{c_1} and stays constant rather than starting from zero as for quasi-particles.

Results from optical measurements and neutron scattering

Optical measurements and neutron scattering have provided especially valuable microscopic information about high T_c superconductors allowing to fix the details of TGD based quantitative model.

Optical measurements of copper oxides in non-super-conducting state have demonstrated that optical conductivity $\sigma(\omega)$ is surprisingly featureless as a function of photon frequency. Below the critical temperature there is however a sharp absorption onset at energy of about 50 meV [D35]. The origin of this special feature has been a longstanding puzzle. It has been proposed that this absorption onset corresponds to a direct generation of an electron-hole pair. Momentum conservation implies that the threshold for this process is $E_g + E$, where E is the energy of the "gluon" which binds electrons of Cooper pair together. In the case of ordinary super-conductivity E would be phonon energy.

Soon after measurements, it was proposed that in absence of lattice excitations photon must generate two electron-hole pairs such that electrons possess opposite momenta [D35]. Hence the energy of the photon would be $2E_g$. Calculations however predicted soft rather than sharp onset of absorption since pairs of electron-hole pairs have continuous energy spectrum. There is something wrong with this picture.

Second peculiar characteristic [D37, D31, D21] of high T_c super conductors is resonant neutron scattering at excitation energy $E_w = 41$ meV of super conductor. This scattering occurs only below the critical temperature, in spin-flip channel and for a favored momentum exchange $(\pi/a, \pi/a))$, where a denotes the size of the lattice cube [D37, D31, D21]. The transferred energy is concentrated in a remarkably narrow range around E_w rather than forming a continuum.

In [D9] is is suggested that e-e resonance with spin one gives rise to this excitation. This resonance is assumed to play the same role as phonon in the ordinary super conductivity and e-e resonance is treated like phonon. It is found that one can understand the dependence of the second derivative of the photon conductivity $\sigma(\omega)$ on frequency and that consistency with neutron scattering data is achieved. The second derivative of $\sigma(\omega)$ peaks near 68 meV and assuming $E = E_g + E_w$ they found nearly perfect match using $E_g = 27$ meV. This would suggest that the energy of the excitations generating the binding between the members of the Cooper pair is indeed 41 meV, that two electron-hole pairs and excitation of the super conductor are generated in photon absorption above threshold, and that the gap energy of the Cooper pair is 27 meV. Of course, the theory of Carbotte *et al* does not force the "gluon" to be triplet excitation of electron pair. Also other possibilities can be considered. What comes in mind are spin flip waves of the spin lattice associated with stripe behaving as spin 1 waves.

In TGD framework more exotic options become possible. The transversal fluctuations of stripes- or rather of the magnetic flux tubes associated with the stripes- could define spin 1 excitations analogous to the excitations of a string like objects. Gauge bosons are identified as wormhole contacts in quantum TGD and massive gauge boson like state containing electron-positron pair or quark-antiquark pair could be considered.

5.4.2 TGD Inspired Vision About High T_c Superconductivity

The following general view about high T_c super-conductivity as quantum critical phenomenon suggests itself. It must be emphasized that this option is one of the many that one can imagine and distinguished only by the fact that it is the minimal option.

The interpretation of critical temperatures

The two critical temperatures T_c and $T_{c_1} > T_c$ are interpreted as critical temperatures. The recent observation that there exists a spectroscopic signature of high T_c super-conductivity, which prevails up to T_{c_1} [D7], supports the interpretation that Cooper pairs exist already below T_{c1} but that for some reason they cannot form a coherent super-conducting state.

One can imagine several alternative TGD based models but for the minimal option is the following one.

1. T_{c_1} would be the temperature for the formation of two-phase system consisting of ordinary electrons and of Cooper pairs with a large value of Planck constant explaining the high

critical temperature.

2. Magnetic flux tubes are assumed to be carriers of supra currents. These flux tubes are very short in in anti-ferromagnetic phase. The holes form stripes making them positively charged so that they attract electrons. If the spins of holes tend to form parallel sequences along stripes, they generate dipole magnetic fields in scales of order stripe length at least. The corresponding magnetic flux tubes are assumed to be carriers of electrons and Cooper pairs. The flux tube structures would be closed so that the supra currents associated with these flux tubes would be trapped in closed loops above T_c.

3. Below T_{c1} transversal fluctuations of the flux tubes structures occur and can induce reconnections giving rise to longer flux tubes. Reconnection can occur in two ways. Recall that upwards going outer flux tubes of the dipole field turn downwards and eventually fuse with the dipole core. If the two dipoles have opposite directions the outer flux tube of the first (second) dipole can reconnect with the inward going part of the flux tube of second (first) dipole. If the dipoles have same direction, the outer flux tubes of the dipoles reconnect with each other. Same applies to the inwards going parts of the flux tubes and the dipoles fuse to a single deformed dipole if all flux tubes reconnect. This alternative looks more plausible. The reconnection process is in general only partial since dipole field consists of several flux tubes.

4. The reconnections for the flux tubes of neighboring almost dipole fields occur with some probability $p(T)$ and make possible finite conductivity. At T_c the system the fluctuations of the flux tubes become large and also $p(T,L)$, where L is the distance between stripes, becomes large and the reconnection leads to a formation of long flux tubes of length of order coherence length at least and macroscopic supra currents can flow. One also expects that the reconnection occurs for practically all flux tubes of the dipole field. Essentially a percolation type phenomenon [D5] would be in question. Scaling invariance suggests $p_c(T,L) = p_c(TL/\hbar)$, where L is the distance between stripes, and would predict the observed $T_c \propto \hbar/L$ behavior. Large value of $\hbar$ would explain the high value of T_c.

This model relates in an interesting manner to the vision of Zaanen [D49] expressed in terms of the highway metaphor visualizing stripes as quantum highways along which Cooper pairs can move. In antiferromagnetic phase the traffic is completely jammed. The doping inducing electron holes allows to circumvent traffic jam due to the Fermi statistics generates stripes along which the traffic flows in the sense of ordinary conductivity. In TGD framework highways are replaced with flux tubes and the topology of the network of highways fluctuates due to the possibility of reconnections. At quantum criticality the reconnections create long flux tubes making possible the flow of supra currents.

The interpretation of fluctuating stripes in terms of 1-D phonons

In TGD framework the phase transition to high T_c super-conductivity would have as a correlate fluctuating stripes to which supra currents are assigned. Note that the fluctuations occur also for $T > T_c$ but their amplitude is smaller. Stripes would be parallel to the dark magnetic flux tubes along which dark electron current flows above T_c. The fluctuations of magnetic flux tubes whose amplitude increases as T_c is approached induce transverse oscillations of the atoms of stripes representing 1-D transverse phonons.

The transverse fluctuations of stripes have naturally spin one character in accordance with the experimental facts. They allow identification as the excitations having 41 meV energy and would propagate in the preferred diagonal direction $(\pi/a, \pi/a)$. Dark Cooper pairs would have a gap energy of 27 meV. Neutron scattering resonance could be understood as a generation of these 1-D phonons and photon absorption a creation of this kind of phonon and breaking of dark Cooper pair. The transverse oscillations could give rise to the gap energy of the Cooper pair below T_{c1} and for the formation of long flux tubes below T_c but one can consider also other mechanisms based on the new physics predicted by TGD.

Various lattice effects such as superconductivity-induced phonon shifts and broadenings, possible isotope effects in T_c (questionable), the penetration depth, infrared and photoemission spectra have been observed in the cuprates [D3]. A possible interpretation is that ordinary phonons are replaced by 1-D phonons defined by the transversal excitations of stripes but do not give rise to the binding of the electrons of the Cooper pair but to reconnection of flux tubes. An alternative proposal which seems to gain experimental support is that spin waves appearing near antiferromagnetic phase transitions replace phonons.

More precise view about high T_c superconductivity taking into account recent experimental results

There are more recent results allowing to formulate more precisely the idea about transition to high T_c super-conductivity as a percolation type phenomenon. Let us first summarize the recent picture about high T_c superconductors.

1. 2-dimensional phenomenon is in question. Supra current flows along preferred lattice planes and type II super-conductivity in question. Proper sizes of Cooper pairs (coherence lengths) are ξ =1-3 nm. Magnetic length λ is longer than $\xi/\sqrt{2}$.
2. Mechanism for the formation of Cooper pairs is the same water bed effect as in the case of ordinary superconductivity. Phonons are only replaced with spin-density waves for electrons with periodicity in general not that of the underlying lattice. Spin density waves relate closely to the underlying antiferromagnetic order. Spin density waves appear near phase transition to antiferromagnetism.
3. The relative orbital angular mentum of Cooper pair is L=2 ($x^2 - y^2$ wave), and vanishes at origin unlike for ordinary s wave SCs. The spin of the Cooper pair vanishes.

Consider now the translation of this picture to TGD language. Basic notions are following.

1. Magnetic flux tubes and possibly also dark electrons forming Cooper pairs.
2. The appearence of spin waves means sequences of electrons with opposite spins. The magnetic field associated with them can form closed flux tube containing both spins. Assume that spins-are orthogonal to the lattice plane in which supracurrent flows. Assume that the flux tube branches associated with electron with given spin branches so that it is shared with both neighboring electrons.
3. Electrons of opposite spins at the two portions of the closed flux tube have magnetic interaction energy. The total energy is minimal when the spins are in opposite directions. Thus the closed flux tube tends to favor formation of Cooper pairs.
4. Since magnetic interaction energy is proportional to $h_{eff} = n \times h$, it is expected stabilize the Cooper pairs at high temperatures. For ordinary super-conducti- vity magnetic fields tends to de-stabilize the pairs by trying to force the spins of spin singlet pair to the same direction.
5. This does not yet give super-conductivity. The closed flux tubes associated with paired spins can however reconnect so that longer flux closed flux tubes are formed. If this occurs for entire sequences, one obtains two flux tubes containing electrons with opposite spins forming Cooper pairs: this would be the "highway" and percolation would corresponds to this process. The pairs would form supracurrents in longer scales.
6. The phase phase transitions generating the reconnections could be percolation type phase transition.

This picture might apply also in TGD based model of bio-superconductivity.

1. The stability of dark Cooper pairs assume to reside at magnetic flux tubes is a problem also now. Fermi statistics favors opposite spins but this means that magnetic field tends to spit the pairs if the members of the pair are at the same flux tube.
2. If the members of the pair are at different flux tubes, the situation changes. One can have $L = 1$ and $S = 1$ with parallel spins (ferromagnetism like situation) or $L = 2$ and $S = 0$ state (anti-ferromagnetism like situation). $L > 0$ is necessary since electrons must reside at separate flux tubes.

Nematics and high T_c superconductors

Waterloo physicists discover new properties of superconductivity is the title of article (see http://tinyurl.com/jfz3l45) popularizing the work of David Hawthorn, Canada Research Chair Michel Gingras, doctoral student Andrew Achkar and post-doctoral student Zhihao Hao published in Science [D23] (see http://tinyurl.com/zycahrx). There is a dose of hype involved. As a matter of fact, it has been known for years that electrons flow along stripes, kind of highways in high T_c superconductors.

This effect is known as nematicity and means that electron orbitals break lattice symmetries and align themselves like a series of rods. Nematicity in long length scales occurs a temperatures below the critical point for super-conductivity. In the above mentioned work cuprate CuO_2 is studied. For non-optimal doping the critical temperature for transition to macroscopic superconductivity is below the maximal critical temperature. Long length scale nematicity is observed in these phases.

In the article by Rosenthal *et al* [D36] (see http://tinyurl.com/h34347f) it is however reported that nematicity is in fact preserved above critical temperature as a local order -at least up to the upper critical temperature, which is not easy to understand in the BCS theory of superconductivity. One can say that the stripes are short and short-lived so that genuine superconductivity cannot take place.

These two observations lend further support for the TGD inspired model of high T_c superconductivity and bio-superconductivity. It is known that antiferromagnetism is essential for the phase transition to superconductivity but Maxwellian view about electromagnetism and standard quantum theory do not make it easy to understand how. Magnetic flux tube is the first basic new notion provided by TGD. Flux tubes carry dark electrons with scaled up Planck constant $h_{eff} = n \times h$: this is second new notion. This implies scaling up of quantal length scales and in this manner makes also super-conductivity possible.

Magnetic flux tubes in antiferromagnetic materials form short loops. At the upper critical point they however reconnect with some probability to form loops with look locally like parallel flux tubes carrying magnetic fields in opposite directions. The probability of reverse phase transition is so large than there is a competion. The members of Cooper pairs are at parallel flux tubes and have opposite spins so that the net spin of pair vanishes: $S = 0$. At the first critical temperature the average length and lifetime of flux tube highways are too short for macroscopic super-conductivity. At lower critical temperature all flux tubes re-connect permantently average length of pathways becomes long enough.

This phase transition is mathematically analogous to percolation in which water seeping through sand layer wets it completely. The competion between the phases between these two temperatures corresponds to quantum criticality in which phase transitions $h_{eff}/h = n_1 \leftrightarrow n_2$ take place in both directions ($n_1 = 1$ is the most plausible first guess). Earlier I did not fully realize that Zero Energy Ontology provides an elegant description for the situation [L27] [?]. The reason was that I thought that quantum criticality occurs at single critical temperature rather than temperature interval. Nematicity is indeed detected locally below upper critical temperature and in long length scales below lower critical temperature.

Explanation for the spectral signatures of high T_c superconductor

The model should explain various spectral signatures of high T_c super-conductors. It seems that this is possible at qualitative level at least.

1. Below the critical temperature there is a sharp absorption onset at energy of about $E_a = 50$ meV.

2. Second characteristic [D37, D31, D21] of high T_c super conductors is resonant neutron scattering at excitation energy $E_w = 41$ meV of super conductor also visible only below the critical temperature.

3. The second derivative of $\sigma(\omega)$ peaks near 68 meV and assuming $E = E_g + E_w$ they found nearly perfect match using $E_g = 27$ meV for the energy gap.

$E_g = 27$ meV has a natural interpretation as energy gap of spin 1 Cooper pair. $E_w = 41$ meV can be assigned to the transversal oscillations of magnetic flux tubes inducing 1-D transversal photons which possibly give rise to the energy gap. $E_a = 50$ meV can be understood if also $S = 0$ Cooper pair for which electrons of the pair reside dominantly at the "outer" dipole flux tube and inner dipole core. The presence of this pair might explain the BCS type aspects of high T_c super-conductivity. This identification would predict the gap energy of $S = 0$ Cooper pair to be $E_g(S = 0) = 9$ meV. Since the critical absorption onset is observed only below T_c these Cooper pairs would become thermally stable at T_c and the formation of long flux tubes should somehow stabilize them. For very long flux tubes the distance of a point of "outer" flux tube from the nearby point "inner" flux tube becomes very long along dipole flux tube. Hence the transformation of $S = 0$ pairs to $S = 1$ pairs is not possible anymore and $S = 0$ pairs are stabilized.

Model for Cooper pairs

The TGD inspired model for Cooper pairs of high T_c super-conductor involves several new physics aspects: large $\hbar$ phases, the notion of magnetic flux tubes. One can also consider the possibility that color force predicted by TGD to be present in all length scales is present.

1. One can consider two options for the topological quantization of the dipole field. It could decompose to a flux tube pattern with a discrete rotational symmetry Z_n around dipole axis or to flux sheets identified as walls of finite thickness invariant under rotations around dipole axis. Besides this there is also inner the flux tube corresponding to the dipole core. For the flux sheet option one can speak about eigenstates of L_z. For flux tube option the representations of Z_n define the counterparts of the angular momentum eigenstates with a cutoff in L_z analogous to a momentum cutoff in lattice. The discretized counterparts of spherical harmonics make sense. The counterparts of the relative angular momentum eigenstates for Cooper pair must be defined in terms of tensor products of these rather than using spherical harmonics assignable with the relative coordinate $r_1 - r_2$. The reconnection mechanism makes sense only for the flux tube option so that it is the only possibility in the recent context.

2. Exotic Cooper pair is modeled as a pair of large $\hbar$ electrons with zoomed up size at space-time representing the dipole field pattern associated with a sequence of holes with same spin. If the members of the pair are at diametrically opposite flux tubes or at the "inner" flux tube (dipole core) magnetic fluxes flow in same direction for electrons and spin 1 Cooper pair is favored. If they reside at the "inner" flux tube and outer flux tube, spin zero state is favored. This raises the question whether also $S = 0$ variant of the Cooper pair could be present.

3. Large $\hbar$ is needed to explain high critical temperature. By the general argument the transition to large $\hbar$ phase occurs in order to reduce the value of the gauge coupling strength - now fine structure constant- and thus guarantee the convergence of the perturbation theory. The generation or positive net charge along stripes indeed means strong electromagnetic interactions at stripe.

Color force in condensed matter length scales is a new physics aspect which cannot be excluded in the case that transverse oscillations of flux tubes do not bind the electrons to form a Cooper pair. Classically color forces accompany any non-vacuum extremal of Kähler action since a non-vanishing induced Kähler field is accompanied by a classical color gauge field with Abelian holonomy. Induced Kähler field is always non-vanishing when the dimension of the CP_2 projection of the space-time surface is higher than 2. One can imagine too alternative scenarios.

1. Electromagnetic flux tubes for which induced Kähler field is non-vanishing carry also classical color fields. Cooper pairs could be color singlet bound states of color octet excitations of electrons (more generally leptons) predicted by TGD and explaining quite impressive number of anomalies [K112]. These states are necessarily dark since the decay widths of gauge bosons do not allow new light fermions coupling to them. The size of these states is of order electron size scale $L(127)$ for the standard value of Planck constant. For the non-standard value of Planck constant it would be scaled up correspondingly. For $r = \hbar/\hbar_0 = 2^{14}$ the size would

be around 3.3 Angströms and for $r = 2^{24}$ of order 10 nm. Color binding could be responsible for the formation of the energy gap in this case and would distinguish between ordinary two-electron states and Cooper pair. The state with minimum color magnetic energy corresponds to spin triplet state for two color octed fermions whereas for colored fermion and anti-fermion it corresponds to spin singlet (pion like state in hadron physics).

2. A more complex variant of this picture served as the original model for Cooper pairs. Electrons at given space-time sheet feed their gauge flux to large space-time sheet via wormhole contacts. If the wormhole throats carry quantum numbers of quark and antiquark one can say that in the simplest situation the electron space-time sheet is color singlet state formed by quark and antiquark associated with the upper throats of the wormhole contacts carrying quantum numbers of u quark and $\overline{d}$ quark. It can also happen that the electronic space-time sheets are not color singlet but color octet in which case the situation is analogous to that above. Color force would bind the two electronic space-time sheets to form a Cooper pair. The neighboring electrons in stripe possess parallel spins and could form a pair transforming to a large $\hbar$ Cooper pair bound by color force. The Coulombic binding energy of the charged particles with the quarks and antiquarks assignable to the two wormhole throats feeding the em gauge flux to Y^4 and color interaction would be responsible for the energy gap.

Estimate for the gap energy

If transverse oscillations are responsible for the binding of the Cooper pairs, one expects similar expression for the gap energy as in the case of BCS type super conductors. The 3-D formula for the gap energy reads as

$$\begin{aligned} E_g &= \hbar\omega_D exp(-1/X) \ , \\ \omega_D &= (6\pi^2)^{1/3} c_s n^{1/3} \\ X &= n(E_F)U_0 = \frac{3}{2}N(E_F)\frac{U_0}{E_F} \ , \\ n(E_F) &= \frac{3}{2}\frac{N(E_F)}{E_F} \ . \end{aligned} \tag{5.4.1}$$

X depends on the details of the binding mechanism for Cooper pairs and U_0 parameterizes these details.

Since only stripes contribute to high T_c super-conductivity it is natural to replace 3-dimensional formula for Debye frequency in 1-dimensional case with

$$\begin{aligned} E_g &= \hbar\omega exp(-1/X) \ , \\ \omega &= kc_s n \ . \end{aligned} \tag{5.4.2}$$

where n is the 1-dimensional density of Cooper pairs and k a numerical constant. X would now correspond to the binding dynamics at the surface of 1-D counterpart of Fermi sphere associated with the stripe.

There is objection against this formula. The large number of holes for stripes suggests that the counterpart of Fermi sphere need not make sense, and one can wonder whether it could be more advantageous to talk about the counterpart of Fermi sphere for holes and treat Cooper pair as a pair of vacancies for this "Fermi sphere". High T_c super conductivity would be 1-D conventional super-conductivity for bound states of vacancies. This would require the replacement of n with the linear density of holes along stripes, which is essentially that of nuclei.

From the known data one can make a rough estimate for the parameter X. If $E_w = hf = 41$ meV is assigned with transverse oscillations the standard value of Planck constant would give $f = f_0 = 9.8 \times 10^{12}$ Hz. In the general case one has $f = f_0/r$. If one takes the 10^{-12} second length scale of the transversal fluctuations at a face value one obtains $r = 10$ as a first guess. $E_g = 27$ meV gives the estimate

$$exp(-1/X) = \frac{E_g}{E_w} \tag{5.4.3}$$

giving $X = 2.39$.

The interpretation in terms of transversal oscillations suggests the dispersion relation

$$f = \frac{c_s}{L} \quad .$$

L is the length of the approximately straight portion of the flux tube. The length of the "outer" flux tube of the dipole field is expected be longer than that of stripe. For $L = x$ nm and $f_D \sim 10^{12}$ Hz one would obtain $c_s = 10^3 x$ m/s.

Estimate for the critical temperatures and for $\hbar$

One can obtain a rough estimate for the critical temperature T_{c1} by following simple argument.

1. The formula for the critical temperature proposed in the previous section generalize in 1-dimensional case to the following formula

$$T_{c1} \leq \frac{h^2}{8m_e}(\frac{n_c}{g})^2 \quad . \tag{5.4.4}$$

   g is the number of spin degrees of freedom for Cooper pair and n_c the 1-D density of Cooper pairs. The effective one-dimensionality allows only single $L = 2$ state localized along the stripe.The $g = 3$ holds true for $S = 1$.

2. By parameterizing n_c as $n_c = (1 - p_h)/a$, $a = x$ Angstrom, and substituting the values of various parameters, one obtains

$$T_{c1} \simeq \frac{r^2(1-p_h)^2}{9x^2} \times 6.3\ meV \quad . \tag{5.4.5}$$

3. An estimate for p_h follows from the doping fraction p_d and the fraction p_s of parallel atomic rows giving rise to stripes one can deduce the fraction of holes for a given stripe as

$$p_h = \frac{p_d}{p_s} \quad . \tag{5.4.6}$$

   One must of course have $p_d \leq p_s$. For instance, for $p_s = 1/5$ and $p_d = 15$ per cent one obtains $p_h = 75$ per cent so that a length of four atomic units along row contains one Cooper pair on the average. For $T_{c1} = 23$ meV (230 K) this would give the rough estimate $r = 23.3$: $r = 24$ satisfies the Fermat polygon constraint. Contrary to the first guess inspired by the model of bio-superconductivity the value of $\hbar$ would not be very much higher than its standard value. Notice however that the proportionality $T_c \propto r^2$ makes it difficult to explain T_{c1} using the standard value of $\hbar$.

4. One $p_h \propto 1/L$ whereas scale invariance for reconnection probability ($p = p(x = TL/\hbar)$) predicts $T_c = x_c\hbar/L = x_c p_s \hbar/a$. This implies

$$\frac{T_c}{T_{c1}} = 32\pi^2\frac{m_e a}{\hbar_0}x^2 g^2 \frac{p_s}{(1-(p_d/p_s)^2)^2}\frac{x_c}{r} \quad . \tag{5.4.7}$$

   This prediction allows to test the proposed admittedly somewhat ad hoc formula. For $p_d << p_s$ T_c/T_{c1} does behaves as $1/L$. One can deduce the value of x_c from the empirical data.

5. Note that if the reconnection probability p is a universal function of x as quantum criticality suggests and thus also x_c is universal, a rather modest increase of $\hbar$ could allow to raise T_c to room temperature range.

The value of $\hbar$ is predicted to be inversely proportional to the density of the Cooper pairs at the flux tube. The large value of $\hbar$ needed in the modelling of living system as magnetic flux tube super-conductor could be interpreted in terms of phase transitions which scale up both the length of flux tubes and the distance between the Cooper pairs so that the ratio rn_c remains unchanged.

Coherence lengths

The coherence length for high T_c super conductors is reported to be 5-20 Angstroms. The naïve interpretation would be as the size of Cooper pair. There is however a loophole involved. The estimate for coherence length in terms of gap energy is given by $\xi = \frac{4\hbar v_F}{E_g}$. If the coherence length is estimated from the gap energy, as it seems to be the case, then the scaling up of the Planck constant would increase coherence length by a factor $r = \hbar/\hbar_0$. $r = 24$ would give coherence lengths in the range $12 - 48$ nm.

The interpretation of the coherence length would be in terms of the length of the connected flux tube structure associated with the row of holes with the same spin direction which can be considerably longer than the row itself. As a matter fact r would characterize the ratio of size scales of the "magnetic body" of the row and of row itself. The coherence lengths could relate to the p-adic length scales $L(k)$ in the range $k = 151, 152, .., 155$ varying in the range $(10, 40])$ nm. $k = 151$ correspond to thickness cell membrane.

Why copper and what about other elements?

The properties of copper are somehow crucial for high T_c superconductivity since cuprates are the only known high T_c superconductors. Copper corresponds to $3d^{10}4s$ ground state configuration with one valence electron. This encourages the question whether the doping by holes needed to achieve superconductivity induces the phase transition transforming the electrons to dark Cooper pairs.

More generally, elements having one electron in s state plus full electronic shells are good candidates for doped high T_c superconductors. If the atom in question is also a boson the formation of atomic Bose-Einstein condensates at Cooper pair space-time sheets is favored. Superfluid would be in question. Thus elements with odd value of A and Z possessing full shells plus single s wave valence electron are of special interest. The six stable elements satisfying these conditions are ^{5}Li, ^{39}K, ^{63}Cu, ^{85}Rb, ^{133}Cs, and ^{197}Au.

A new phase of matter in the temperature range between pseudo gap temperature and T_c?

Kram sent a link to a Science Daily popular article titled "High-Temperature Superconductor Spills Secret: A New Phase of Matter?" (see `http://tinyurl.com/49vnvsu`: see also `http://tinyurl.com/yb7rs3fs`). For more details see the article in Science [D25].

Zhi-Xun Shen of the Stanford Institute for Materials and Energy Science (SIMES), a joint institute of the Department of Energy's SLAC National Accelerator Laboratory and Stanford University, led the team of researchers, which discovered that in the temperature region between the pseudo gap temperature and genuine temperature for the transition to super-conducting phase there exists a new phase of matter. The new phase would not be super-conducting but would be characterized by an order of its own which remains to be understood. This phase would be present also in the super-conducting phase.

The announcement does not come as a complete surprise for me. A new phase of matter is what TGD inspired model of high T_c superconductivity indeed predicts. This phase would consist of Cooper pairs of electrons with a large value of Planck constant but associated with magnetic flux tubes with short length so that no macroscopic supra currents would be possible.

The transition to super-conducting phase involves long range fluctuations at quantum criticality and the analog of a phenomenon known as percolation (see `http://tinyurl.com/oytvosv`) [D5]. For instance, the phenomenon occurs for the filtering of fluids through porous materials.

At critical threshold the entire filter suddenly wets as fluid gets through the filter. Now this phenomenon would occur for magnetic flux tubes carrying the Cooper pairs. At criticality the short magnetic flux tubes fuse by reconnection to form long ones so that supra currents in macroscopic scales become possible.

It is not clear whether this prediction is consistent with the finding of Shen and others. The simultaneous presence of short and long flux tubes in macroscopically super-conducting phase is certainly consistent with TGD prediction. The situation depends on what one means with super-conductivity. Is super-conductivity super-conductivity in macroscopic scales only or should one call also short scale super-conductivity not giving rise to macroscopic super currents as super-conductivity. In other words: do the findings of Shen's team prove that the electrons above gap temperature do not form Cooper pairs or only that there are no macroscopic supra currents?

Whether the model works as such or not is not a life and death question for the TGD based model. One can quite well imagine that the first phase transition increasing $\hbar$ does not yet produce electron Compton lengths long enough to guarantee that the overlap criterion for the formation of Cooper pairs is satisfied. The second phase transition increasing $\hbar$ would do this and also scale up the lengths of magnetic flux tubes making possible the flow of supra currents as such even without reconnections. Also reconnections making possible the formation of very long flux tubes could be involved and would be made possible by the increase in the length of flux tubes.

5.4.3 Speculations

21-Micrometer mystery

21 micrometer radiation from certain red giant stars have perplexed astronomers for more than a decade [D8]. Emission forms a wide band (with width about 4 micrometers) in the infrared spectrum, which suggests that it comes form a large complex molecule or a solid or simple molecules found around starts. Small molecules are ruled out since they produce narrow emission lines. The feature can be only observed in very precise evolutionary state, in the transition between red giant phase and planetary nebular state, in which star blows off dust that is rich in carbon compounds. There is no generally accepted explanation for 21-micrometer radiation.

One can consider several explanations based on p-adic length scale hypothesis and some explanations might relate to the wormhole based super-conductivity.

1. 21 micrometers corresponds to the photon energy of 59 meV which is quite near to the zero point point kinetic energy 61.5 meV of proton Cooper pair at $k = 139$ space-time sheet estimated from the formula

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

   Here the binding energy of the Cooper pair tending to reduce this estimate is neglected, and this estimate makes sense only apart from a numerical factor of order unity. This energy is liberated when a Cooper pair of protons at $k = 139$ space-time sheet drops to the magnetic flux tube of Earth's magnetic field (or some other sufficiently large space-time sheet). This energy is rather near to the threshold value about 55 meV of the membrane potential.

2. 21 micrometer radiation could also result when electrons at $k = 151$ space-time sheet drop to a large enough space-time sheet and liberate their zero point kinetic energy. Scaling argument gives for the zero point kinetic energy of electron at $k = 151$ space-time sheet the value $\Delta(e, 151) \simeq 57.5$ meV which is also quite near to the observed value. If electron is bound to wormhole with quantum numbers of $\overline{d}$ Coulombic binding energy changes the situation.

3. A possible explanation is as a radiation associated with the transition to high T_c super conducting phase. There are two sources of photons. Radiation could perhaps result from the de-excitations of wormhole BE condensate by photon emission. $\lambda = 20.5$ micrometers is precisely what one expects if the space-time sheet corresponds to $p \simeq 2^k$, $k = 173$ and assumes that excitation energies are given as multiples of $E_w(k) = 2\pi/L_e(k)$. This predicts

excitation energy $E_w(173) \simeq 61.5$ meV. Unfortunately, this radiation should correspond to a sharp emission line and cannot explain the wide spectrum.

Are living systems high T_c superconductors?

The idea about cells and axons as superconductors has been one of the main driving forces in development of the vision about many-sheeted space-time. Despite this the realization that the supra currents in high T_c superconductors flow along structure similar to axon and having same crucial length scales came as a surprise. Axonal radius which is typically of order $r = .5$ μm. $r = 151 - 127 = 24$ favored by Mersenne hypothesis would predict $r = .4$ μm. The fact that water is liquid could explain why the radius differs from that predicted in case of high T_c superconductors.

Interestingly, Cu is one of the biologically most important trace elements [D2]. For instance, copper is found in a variety of enzymes, including the copper centers of cytochrome c-oxidase, the Cu-Zn containing enzyme superoxide dismutase, and copper is the central metal in the oxygen carrying pigment hemocyanin. The blood of the horseshoe crab, Limulus polyphemus uses copper rather than iron for oxygen transport. Hence there are excellent reasons to ask whether living matter might be able to build high T_c superconductors based on copper oxide.

Neuronal axon as a geometric model for current carrying "rivers"

Neuronal axons, which are bounded by cell membranes of thickness $L_e(151)$ consisting of two lipid layers of thickness $L_e(149)$ are good candidates for high T_c superconductors in living matter.

These flux tubes with radius .4 μm would define "rivers" along which conduction electrons and various kinds of Cooper pairs flow. Scaled up electrons have size $L_e(k_{eff} = 151)$ corresponding to 10 nm, the thickness of the lipid layer of cell membrane. Also the quantum fluctuating stripes of length 1-10 nm observed in high T_c super conductors might relate to the scaled up electrons with Compton length 10 nm, perhaps actually representing zoomed up electrons!

The original assumption that exotic *resp.* BCS type Cooper pairs reside at boundaries *resp.* interior of the super-conducting rivulet. It would however seem that the most natural option is that the hollow cylindrical shells carry all supra currents and there are no Cooper pairs in the interior. If exotic Cooper pairs reside only at the boundary of the rivulet or the Cooper pairs at boundary remain critical against exotic-BCS transition also below T_c, the time dependent fluctuations of the shapes of stripes accompanying high T_c super-conductivity can be understood as being induced by the fluctuations of membrane like structures. Quantum criticality at some part of the boundary is necessary in order to transform ordinary electron currents to super currents at the ends of rivulets. In biology this quantum criticality would correspond to that of cell membrane.

5.5 Quantitative Model Of High T_c Super-Conductivity And Bio-Super-Conductivity

I have developed already earlier [K21, K22, K79, K80] a rough model for high T_c super conductivity [D46, D48, D49, D16, D7, D52]. The members of Cooper pairs are assigned with parallel flux tubes carrying fluxes which have either same or opposite directions. The essential element of the model is hierarchy of Planck constants defining a hierarchy of dark matters.

1. In the case of ordinary high T_c super-conductivity bound states of charge carriers at parallel short flux tubes become stable as spin-spin interaction energy becomes higher than thermal energy.

   The transition to super-conductivity is known to occur in two steps: as if two competing mechanisms were at work. A possible interpretation is that at higher critical temperature Cooper pairs become stable but that the flux tubes are stable only below rather short scale: perhaps because the spin-flux interaction energy for current carriers is below thermal energy. At the lower critical temperature the stability would is achieved and supra-currents can flow in long length scales.

2. The phase transition to super-conductivity is analogous to a percolation process in which flux tube pairs fuse by a reconnection to form longer super-conducting pairs at the lower critical

temperature. This requires that flux tubes carry anti-parallel fluxes: this is in accordance with the anti-ferro-magnetic character of high T_c super conductivity. The stability of flux tubes very probably correlates with the stability of Cooper pairs: coherence length could dictate the typical length of the flux tube.

3. A non-standard value of h_{eff} for the current carrying magnetic flux tubes is necessary since otherwise the interaction energy of spin with the magnetic field associated with the flux tube is much below the thermal energy.

There are two energies involved.

1. The spin-spin-interaction energy should give rise to the formation of Cooper pairs with members at parallel flux tubes at higher critical temperature. Both spin triplet and spin singlet pairs are possible and also their mixture is possible.

2. The interaction energy of spins with magnetic fluxes, which can be parallel or antiparallel contributes also to the gap energy of Cooper pair and gives rise to mixing of spin singlet and spin triplet. In TGD based model of quantum biology antiparallel fluxes are of special importance since U-shaped flux tubes serve as kind of tentacles allow magnetic bodies form pairs of antiparallel flux tubes connecting them and carrying supra-currents. The possibility of parallel fluxes suggests that also ferro-magnetic systems could allow super-conductivity.

   One can wonder whether the interaction of spins with magnetic field of flux tube could give rise to a dark magnetization and generate analogs of spin currents known to be coherent in long length scales and used for this reason in spintronics (`http://tinyurl.com/5cu3qh`). One can also ask whether the spin current carrying flux tubes could become stable at the lower critical temperature and make super-conductivity possible via the formation of Cooper pairs. This option does not seem to be realistic.

In the following the earlier flux tube model for high T_c super-conductivity and bio-super-conductivity is formulated in more precise manner. The model leads to highly non-trivial and testable predictions.

1. Also in the case of ordinary high T_c super-conductivity large value of $h_{eff} = n \times h$ is required.

2. In the case of high T_c super-conductivity two kinds of Cooper pairs, which belong to spin triplet representation in good approximation, are predicted. The average spin of the states vanishes for antiparallel flux tubes. Also super-conductivity associated with parallel flux tubes is predicted and could mean that ferromagnetic systems could become super-conducting.

3. One ends up to the prediction that there should be a third critical temperature T^{**} not lower than $T^{**}_{min} = 2T^*/3$, where T^* is the higher critical temperature at which Cooper pairs identifiable as mixtures of $S_z = \pm 1$ pairs emerge. At the lower temperature $S_z = 0$ states, which are mixtures of spin triplet and spin singlet state emerge. At temperature T_c the flux tubes carrying the two kinds of pairs become thermally stable by a percolation type process involving re-connection of U-shaped flux tubes to longer flux tube pairs and supra-currents can run in long length scales.

4. The model applies also in TGD inspired model of living matter. Now however the ratio of critical temperatures for the phase transition in which long flux tubes stabilize is roughly by a factor 1/50 lower than that in which stable Cooper pairs emerge and corresponds to thermal energy at physiological temperatures which corresponds also the cell membrane potential. The higher energy corresponds to the scale of bio-photon energies (visible and UV range).

5.5.1 A More Detailed Flux Tube Model For Super-Conductivity

The following little calculations support the above vision and lead to quite predictive model.

5.5.2 Simple Quantitative Model

It is best to proceed by building a quantitative model for the situation.

1. Spin-spin interaction energy for electron pair with members de-localized at parallel magnetic flux tubes must be deduced from the standard expression for the magnetic field created by the second charge and from the expression for the magnetic interaction energy of magnetic moment with external magnetic field.

   The magnetic field created by dipole μ outside the dipole is given by

$$B = \frac{\mu_0}{4\pi a^3} \times (3nn \cdot \mu - \mu) \ . \tag{5.5.1}$$

   The factor $\frac{\mu_0}{4\pi}$ can be taken equal to $1/4\pi$ as unity in the units in which $\mu_0 = \epsilon_0 = c = 1$ holds true. n is direction vector associated with the relative position vector a.

   The magnetic interaction energy reads as $E = -\mu \cdot B$ and in the case of identical magnetic moments reads as

$$E = \frac{1}{4\pi a^3} \times (-3\mu_1 \cdot n\mu_2 \cdot n + \mu_1 \cdot \mu_2) \ . \tag{5.5.2}$$

2. The magnetic dipole moment of electron is $\mu = -(ge/2m)S$, $S = \hbar/2$, $g \simeq 2$. For proton analogous expression holds with Lande factor $g = 5.585694713(46)$.

A simple model is obtained by assuming that the distance between the members of Cooper pair is minimal so that the relative position vector is orthogonal to the flux tubes.

1. This gives for the spin-spin interaction Hamiltonian the expression

$$H_{s-s} = \frac{1}{4\pi a^3} \times (\frac{ge\hbar}{2m})^2 \times O \ , \quad O = -3(m_1)_x(m_2)_x + m_1 \cdot m_2 \ . \tag{5.5.3}$$

   m_i refers to spin in units of $\hbar$. x referes to the direction in the plane defined by flux tubes and orthogonal to them. m_x can be expressed in terms of spin raising and lowering operators as $m_x = (1/2)(m_+ + m_-)$, $m_\pm = m_x \pm im_y$. This gives

$$(m_1)_x(m_2)_x = \frac{1}{4}\sum_{i=\pm,j=\pm}(m_i)_1(m_j)_2 \ . \tag{5.5.4}$$

   $m_1 \cdot m_2$ can be expressed as $(1/2) \times [(m_1+m_2)^2 - m_1^2 - m_2^2]$. In the case of spin 1/2 particles one can have spin singlet and spin triplet and the value of $m_1 \cdot m_2$ is in these cases given by $m_1 \cdot m_2(singlet) = -3/4$ and $m_1 \cdot m_2(triplet) = 1/4$

   The outcome is an expression for the spin-spin interaction Hamiltonian

$$\begin{aligned} &H_{s-s} = E_{s-s} \times O \ , \quad E_{s-s} = \frac{1}{4\pi a^3} \times (ge\hbar/2m)^2 \times O \ , \\ &O = O_1 + O_2(S) \ , \quad O_1 = -\frac{3}{4}\sum_{i=\pm,j=\pm}(m_i)_1(m_j)_2 \ , \\ &O_2(singlet) = -\frac{3}{4} \ , \quad O_2(triplet) = \frac{1}{4} \ . \end{aligned} \tag{5.5.5}$$

2. The total interaction Hamiltonian of magnetic moment with the magnetic field of flux tube can be deduced as

$$\begin{aligned} & H_{s-flux} = -(\mu_Z)_1 B_1 - (\mu_Z)_2 B_2 = \tfrac{ge}{\hbar 2m}(m_1)_z B_1 + (m_2)_z B_2 \\ & = E_{s-flux} \times ((m_1)_z + \epsilon(m_2)_z) \ , \ E_{s-flux} = \tfrac{ge\hbar B}{2m} \ . \end{aligned} \tag{5.5.6}$$

3. For the diagonalization of spin-spin interaction Hamiltonian the eigenbasis of S_z is a natural choice. In this basis the only non-diagonal terms are O_1 and E_{s-flux}. O_1 does not mix representations with different total spin and is diagonal for the singlet representation. Also the $S_z(tot) = 0$ state of triplet representation is diagonal with respect to O_1: this is clear from the explicit representation matrices of spin raising and lowering operators (the non-vanishing elements in spin 1/2 representation are equal to 1). $S_z(tot) = 0$ states are eigenstates of O_1 with eigenvalue $+3/4$ for singlet and $-3/4$ for triplet. For singlet one therefore has eigenvalue $o = 0$ and for triplet eigenvalue $o = -1/2$. Singlet does not allow bound state whereas triplet does.

   $S_z(tot) = 1$ and $S_z(tot) = -1$ states are mixed with each other. In this case the O_1 has non-diagonal matrix elements equal to $O_1(1,-1) = O_1(-1,1) = 1$ so that the matrix representing O is given by

$$O = \begin{pmatrix} \frac{1}{4} & 1 \\ 1 & \frac{1}{4} \end{pmatrix} \ . \tag{5.5.7}$$

   The eigenvalues are $o_+ = 5/4$ and $o_- = -3/4$. Cooper pairs states are linear combinations of $S_z = \pm 1$ states with coefficients with have either same or opposite sign so that a maximal mixing occurs and the average spin of the pair vanishes.

   To sum up, there are two bound states for mere spin-spin interaction corresponding to $o = -1/2$ spin 0 triplet state and $o = -3/4$ state for which spin 1 and spin -1 states are mixed.

4. For spin singlet at parallel flux tubes the spin-flux interaction vanishes: $H(para, singlet) = 0$. Same holds true for $S_z = \pm 1$ states at biologically especially interesting antiparallel flux tubes: $H(anti, S_z = \pm 1) = 0$. For antiparallel flux tubes $S_z = 0$ states in singlet and triplet are mixed by $H(anti, S_z = 0)$. The two resulting states must have negative binding energy so that one obtains 3 bound states altogether and only one state remains unbound. The amount of mixing and thermal stability of possibly slightly perturbed singlet state is determined by the ratio x of the scale parameters of H_{s-flux} and H_{s-s}.

   The explicit form of $H(anti, S_z = 0)$ is

$$\begin{aligned} H(anti, S_z = 0) &= -\frac{E_{s-s}}{2} \begin{pmatrix} 1 & x \\ x & 0 \end{pmatrix} \\ x = -\frac{4E_{s-flux}}{E_{s-s}} &= -32\pi \frac{ma^3}{ge\hbar B} \ , \\ E_{s-s} &= \frac{1}{8\pi}(\frac{ge\hbar}{2m})^2 \frac{1}{a^3} \ . \end{aligned} \tag{5.5.8}$$

   The eigenvalues $H(anti, S_z = 0)$

$$E_\pm = -\frac{E_{s-s}}{4}(1 \pm \sqrt{1 + 4x^2}) \ . \tag{5.5.9}$$

What is remarkable is that both parallel antiparallel flux tubes give rise to 2 bound states assignable to spin triplet. Singlet does not allow bound states.

5. The Planck constant appearing in the formulas can be replaced with $\hbar_{eff} = n\hbar$. Note that the value of the parameter x is inversely proportional to h_{eff} so that singlet approximation improves for large values of h_{eff}.

5.5.3 Fermionic Statistics And Bosons

What about fermionic statistics and bosons?

1. The total wave function must be antisymmetric and the manner to achieve this for spin triplet state is anti-symmetrization in longitudinal degrees of freedom. In 3-D model for Cooper pairs spatial antis-ymmetrization implies $L = 1$ spatial wave function in the relative coordinate and one obtains $J = 0$ and $J = 2$ states. Now the state could be antisymmetric under the exchange of longitudinal momenta of fermions. Longitudinal momenta cannot be identical and Fermi sphere is replaced by its 1-dimensional variant. In 3-D model for Cooper pairs spatial anti-symmetrization implies $L = 1$ spatial wave function in the relative coordinate. Antisymmetry with respect to longitudinal momenta would be the analog for the odd parity of this wave function. Ordinary super-conductivity is located at the boundary of Fermi sphere in a narrow layer with thickness defined by the binding energy. The situation is same now and the thickness should correspond now to the spin-flux interaction energy.

2. Second possibility is more exotic and could be based on antisymmetric entanglement in discrete dark degrees of freedom defined by the sheets of the singular covering assignable to the integer $n = h_{eff}/h$. For $n = 2m$ one can decompose the n discrete degrees of freedom to the discrete analogs of m spatial coordinates q_i and m canonical momenta p_i and assume that the entanglement matrix proportional to a unitary matrix (negentropic entanglement) is proportional to the standard antisymmetric matrix defining symplectic structure and expressible as a direct sum of 2×2 permutation symbols ϵ_{ij}. $J_{p_i,q_i} = -J_{q_i p_i} = 1/\sqrt{2m}$. This matrix is antisymmetric and unitary in standard sense and quaternionic sense.

3. What about bosons? I have proposed that bosonic ions (such as Ca^{++}) associated with single flux tube form cyclotron Bose Einstein condensates giving rise to spontaneous dark magnetization. Bosonic supra currents can indeed run independently along single flux tube as spin currents. Also now the thermal stability of cyclotron states require large h_{eff}. The supra-currents (spin currents) of bosonic ions could be associated with flux tubes and fermionic supra-currents with their pairs. Even dark photons could give rise to spin currents.

   At the formal level the model applies in the case of bosons too. Symmetrization/anti-symmetrization for spin singlets/triplets would be replaced with anti-symmetrization/symmetrization. The analog of Fermi sphere would be obtained for spin singlet states requiring anti-symmetrization in longitudinal degrees of freedom.

5.5.4 Interpretation In The Case Of High T_c Super-Conductivity

It is interesting to try to interpret the results in terms of high T_c super-conductivity (`http://tinyurl.com/yd8vj9g`).

1. The four eigen values of total Hamiltonian are

$$E = E_{s-s} \times \lambda \ ,$$

$$\lambda \in \{\frac{5}{4}, -\frac{3}{4}, -\frac{1}{4}(1 \pm \sqrt{1+4x^2})\} \ . \qquad (5.5.10)$$

   Two bound states with different binding energies are obtained which should be an empirically testable prediction in the case of the ordinary high T_c superconductivity since it predicts two critical temperatures. Cooper pairs are apart from possible small mixing with singlet state triplet states. The average spin is however vanishing also for $S_z = \pm 1$ states-

2. Two phase transitions giving rise to Cooper pairs are predicted. The simplest interpretation would be that super-conductivity in short scales is already present below the higher critical temperature and corresponds to the currents carries forming a mixture of $S_z = \pm 1$ states. These supra currents would stabilize flux tubes below some rather short scale. At the lower critical temperature the super-conductivity assignable to $S_z = 0$ spin triplets slightly mixed with singlet would become possible and the scale in which supra-currents can run would increase due to the occurrence of the percolation phenomenon. Below the lower critical temperature the interaction with flux tubes is indeed involved in an essential manner as a mixing of singlet and triplet states. One could perhaps say that $S_z = 0$ states stabilize the flux tube pair.

3. The critical temperatures for the stability of Cooper pairs are predicted to be in ratio $3/1 + \sqrt{1+4x^2}$ roughly equal the upper bound 3/2 for small x. The critical temperatures are identical for $x = \sqrt{63/4} \simeq 4$. In the ordinary high T_c super-conductivity in cuprates the two critical temperatures are around $T^* = 300$K and $T_c = 80K$. The ratio $T^*/T_c = 3.75$ fails to be consistent with the upper bound 3/2.

4. If one takes the model deadly seriously despite its strong simplifying assumptions one is forced to consider a more complex interpretation. What comes in mind is that both kind of Cooper pairs appear first and super-conductivity becomes possible at T_c. T^* would correspond to the emergence of $S_z = \pm 1$ mixtures. The critical temperature T^{**} for the emergence $S_z = 0$ pairs would not be lower than $T^{**}_{min} = (2/3) \times 300 = 200$ K. At temperature T_c the flux tubes carrying the two kinds of pairs become thermally stable by a percolation type process involving re-connection of U-shaped flux tubes to longer flux tube pairs and supra-currents can run in long length scales. This model conforms with the interpretation of pseudo-gap in terms o pre-formed Cooper pairs not able to form coherent supra-currents (`http://tinyurl.com/yc543vbl`).

One ends up to the prediction that there should be a third critical temperature T^{**} not lower than $T^{**}_{min} = 2T^*/3$, where T^* is the higher critical temperature at which Cooper pairs identifiable as mixtures of $S_z = \pm 1$ pairs emerge. At the lower temperature $S_z = 0$ states, which are mixtures of spin triplet and spin singlet state emerge.

5.5.5 Quantitative Estimates In The Case Of TGD Inspired Quantum Biology

Using the formulas obtained above one can make rough quantitative estimates and get grasp about bio-super-conductivity as predicted by the model.

1. To get grasp to the situation it is good to consider as starting point electron with nanometer scale $a = a_0 = 1$ nm taken as the distance between flux tubes. For $h_{eff} = n \times h$ value of Planck constant one obtains $E_{s-s} = n^2(a/a_0)^3 \times E_0$. $E_0 = 1.7 \times 10^{-7}$ eV.

   Taking $B = 1$ Tesla one obtains for E_{s-flux} $E_{s-flux} = n \times E_{s-flux,0}$, $E_{s-flux,0} = 6.2 \times 10^{-7}$ eV. For $B = B_{end} = .2$ Gauss suggested as an important value of dark endogenous magnetic field one obtains $E_{s-flux,0} = 2.5 \times 10^{-11}$ eV.

2. It seems reasonable to require that the two interaction energies are of same order of magnitude. Spin-flux interaction energy is rather small. For instance, for B=1 Tesla its magnitude for electron is about $E_{s-flux,0} = 6.2 \times 10^{-7}$ eV so that a large value of h_{eff} seems to be necessary.

3. The hypothesis that bio-photons result in the transformations of dark photons to ordinary photons suggests that the energy scale is in the range of visible and UV photons and therefore above eV. This suggests for electron $h_{eff}/h = n \geq 10^7$. The condition that the value of E_{s-s} is also in the same range requires that a scales like $n^{1/3}$. This would give scaling, which is larger than $10^{7/3} \simeq 215$: this would mean $a \geq 2 \times 10^{-7}$ m which belongs to the range of biologically most important length scales between cell membrane thickness and nucleus size.

4. The hypothesis $\hbar_{eff} = n \times \hbar = \hbar_{gr} = GMm/v_0$ [K74, ?] implies that cyclotron energy spectrum is universal (no dependence on the mass of the charged particle. Same would hold true for the spin-flux interaction energy. Spin spin interaction energy is proportional to h_{eff}^2/m^2a^3, where a is minimum distance between members of the Cooper pair. It is invariant under the simultaneous scaling of h_{eff} and m so that all charged particles can form Cooper pairs and spin currents for flux tubes with same distance and same magnetic field strength. This would correspond to the universality of the bio-photons [K15]. This would be also consistent with the earlier explanation for the finding of Hu and Wu [J46] that proton spin-spin interaction frequency for the distance defined by cell membrane thickness is in ELF frequency scale. The proposal was that dark proton sequences are involved at both sides of the membrane.

   Universality of Cooper pair binding energies implies universality of super-conductivity all fermionic ions can form superconducting Cooper pairs as has been assumed in the models for strange effects of ELF em fields on vertebrate brain, for cell membrane as Josephson junction, and for EEG [K37], and in the model for nerve pulse [K82]. As found, Bose-Einstein condensates of bosonic ions could give rise to spontaneous dark magnetization and spin currents along single flux tube so that bosons would be associated with flux tubes and fermions with pairs of them.

   The value of h_{eff} for proton would satisfy $n \geq 2 \times 10^{10}$. This would guarantee that proton cyclotron frequency for $B = B_{end}$ corresponds to thermal energy 2.5×10^{-2} eV at room temperature.

   Note that I have considered also the option that the values of h_{eff} are such that the universal cyclotron energy scale in magnetic field of $B \simeq .2$ Gauss is in the range of bio-photon energies so that h_{eff} would be by a factor of order 50 higher than in the estimate coming from spin temperature.

5. This observation raises the question whether there are two widely different energy scales present in living matter. The first scale would be associated with spin-spin interaction and would correspond to the energy scale of bio-photons. Second scale would be associated with spin-flux interaction and correspond to the energy scale of resting potential just above the thermal energy at physiological temperatures.

   If this is the case, the parameter x would be of order $x \simeq 10^{-2}$ and spin-spin interaction energy would dominate. The somewhat paradoxical earlier prediction was that Cooper pairs in bio-super-conductivity would be stable at temperatures corresponding to energy of eV or even higher but organisms do not survive above physiological temperatures. The critical temperature for living matter could be however understood in terms of the temperature sensitivity of the dark magnetization at magnetic flux tubes. Although the binding energies of Cooper pairs are in bio-photon energy range this does not help since the quantum wires along, which they can propagate are unstable above room temperatures.

6. From the estimate of order 10^{-7} eV for energy scales for $a = 1$ nm and $B = 1$ Tesla and from the binding energy of Cooper pairs of order 10^{-2} eV it is clear that ordinary high T_c super-conductivity cannot correspond to the standard value of Planck constant: $h_{eff}/h \simeq 10^5$ is required. The interpretation would be that at the higher critical temperature Cooper pairs become stable but flux tubes are not stable. At the lower critical temperature also flux tubes become stable. This would correspond to the percolation model that I have proposed earlier.

   These two energy scales would be the biological counterparts of the two much lower energy scales in the ordinary high T_c super-conductivity. There ratio of these scales would be roughly 50.

5.5.6 Does Also Low Tc Superconductivity Rely On Magnetic Flux Tubes In TGD Universe?

Discussions with Hans Geesink have inspired sharpening of the TGD view about bio-superconductivity (bio-SC), high Tc superconductivity (SC) and relate the picture to standard descriptions in a more detailed manner. In fact, also standard low temperature super-conductivity modelled using BCS theory could be based on the same universal mechanism involving pairs of magnetic flux tubes possibly forming flattened square like closed flux tubes and members of Cooper pairs residing at them.

A brief summary about strengths and weakness of BCS theory

First I try to summarize basics of BCS theory.

1. BCS theory is successful in 3-D superconductors and explains a lot: supracurrent, diamagnetism, and thermodynamics of the superconducting state, and it has correlated many experimental data in terms of a few basic parameters.

2. BCS theory has also failures.

   (a) The dependence on crystal structure and chemistry is not well-understood: it is not possible to predict, which materials are super-conducting and which are not.

   (b) High-Tc SC is not understood. Antiferromagnetism is known to be important. The quite recent experiment demonstrates conductivity- maybe even conductivity - in topological insulator in presence of magnetic field [L20]. This is compete paradox and suggests in TGD framework that the flux tubes of external magnetic field serve as the wires [L20].

3. BCS model based on crystalline long range order and k-space (Fermi sphere). BCS-difficult materials have short range structural order: amorphous alloys, SC metal particles 0-down to 50 Angstroms (lipid layer of cell membrane) transition metals, alloys, compounds. Real space description rather than k-space description based on crystalline order seems to be more natural. Could it be that the description of electrons of Cooper pair is not correct? If so, k-space and Fermi sphere would be only appropriate description of ordinary electrons needed to model the transition to to super-conductivity? Super-conducting electrons could require different description.

4. Local chemical bonding/real molecular description has been proposed. This is of course very natural in standard physics framework since the standard view about magnetic fields does not provide any ideas about Cooper pairing and magnetic fields are only a nuisance rather than something making SC possible. In TGD framework the situation is different.

TGD based view about SC

TGD proposal for high Tc SC and bio-SC relies on many-sheeted space-time and TGD based view about dark matter as $h_{eff} = n \times h$ phase of ordinary matter emerging at quantum criticality [K80].

Pairs of dark magnetic flux tubes would be the wires carrying dark Cooper pairs with members of the pair at the tubes of the pair. If the members of flux tube pair carry opposite B:s, Cooper pairs have spin 0. The magnetic interaction energy with the flux tube is what determines the critical temperature. High Tc superconductivity, in particular the presence of two critical temperatures can be understood. The role of anti-ferromagnetism can be understood.

TGD model is clearly x-space model: dark flux tubes are the x-space concept. Momentum space and the notion of Fermi sphere are certainly useful in understanding the transformation ordinary lattice electrons to dark electrons at flux tubes but the super conducting electron pairs at flux tubes would have different description.

Now come the heretic questions.

1. Do the crystal structure and chemistry define the only fundamental parameters in SC? Could the notion of magnetic body - which of course can correlate with crystal structure and chemistry - equally important or even more important notion?

2. Could also ordinary BCS SC be based on magnetic flux tubes? Is the value of $h_{eff} = n \times h$ only considerably smaller so that low temperatures are required since energy scale is cyclotron energy scale given by E= $h_{eff} = n \times f_c$, $f_c = eB/m_e$. High Tc SC would only have larger h_{eff} and bio-superconductivity even larger h_{eff}!

3. Could it be that also in low Tc SC there are dark flux tube pairs carrying dark magnetic fields in opposite directions and Cooper pairs flow along these pairs? The pairs could actually form closed loops: kind of flattened O:s or flattened squares.

One must be able to understand Meissner effect. Why dark SC would prevent the penetration of the ordinary magnetic field inside superconductor?

1. Could B_{ext} actually penetrate SC at its own space-time sheet. Could opposite field B_{ind} at its own space-time sheet effectively interfere it to zero? In TGD this would mean generation of space-time sheet with $B_{ind} = -B_{ext}$ so that test particle experiences vanishing B. This is obviously new. Fields do not superpose: only the effects caused by them superpose.

   Could dark or ordinary flux tube pairs carrying B_{ind} be created such that the first flux tube portion B_{ind} in the interior cancels the effect of B_{ext} on charge carriers. The return flux of the closed flux tube of B_{ind} would run outside SC and amplify the detected field B_{ext} outside SC. Just as observed.

2. What happens, when B_{ext} penetrates to SC? $h_{eff} \to h$ must take place for dark flux tubes whose cross-sectional area and perhaps also length scale down by h_{eff} and field strength increases by h_{eff}. If also the flux tubes of B_{ind} are dark they would reduce in size in the transition $h_{eff} \to h$ by $1/h_{eff}$ factor and would remain inside SC! B_{ext} would not be screened anymore inside superconductor and amplified outside it! The critical value of B_{ext} would mean criticality for this $h_{eff} \to h$ phase transition.

3. Why and how the phase transition destroying SC takes place? Is it energetically impossible to build too strong B_{ind}? So that effective field $B_{eff} = B_{dark} + B_{ind} + B_{ext}$ experienced by electrons is reduced so that also the binding energy of Cooper pair is reduced and it becomes thermally unstable. This in turn would mean that Cooper pairs generating the dark B_{dark} disappear and also B_{dark} disappears. SC disappears.

Wee after writing the above text came the newest news concerning high Tc superconductivity. Hydrogen sulfide - the compound responsible for the smell of rotten eggs - conducts electricity with zero resistance at a record high temperature of 203 Kelvin (−70 degrees C), reports a paper published in Nature. This super-conductor however suffers from a serious existential crisis: it behaves very much like old fashioned super-conductor for which superconductivity is believed to be caused by lattice vibrations and is therefore not allowed to exist in the world of standard physics! To be or not to be!

TGD Universe allows however all flowers to bloom: the interpretation is that the mechanism is large enough value of $h_{eff} = n \times h$ implying that critical temperature scales up. Perhaps it is not a total accident that hydrogen sulfide H2S - chemically analogous to water - results from the bacterial breakdown of organic matter, which according to TGD is high temperature superconductor at room temperature and mostly water, which is absolutely essential for the properties of living matter in TGD Universe.

As a matter fact, H_2S is used by some bacteria living in deep ocean volcanic vents as a nutrient and also in our own gut: chemically this means that H_2S acts as electron donor in primitive photosynthesis like process to give ATP. That sulphur is essential for growth and physical functioning of plants might be due to the fact that it preceded oxygen based life [F1]. For instance, Cys and met containing sulphur are very important amino-acids.

Indications for high T_c superconductivity at 373 K with $h_{eff}/h = 2$

Some time ago I learned about a claim of Ivan Kostadinov [D44] about superconductivity at temperature of 373 K (100 C) (see `http://tinyurl.com/y9hk83ak`). There is also claims by E. Joe Eck about superconductivity: the latest at 400 K [D15] (see `http://tinyurl.com/yc483hsf`). I am not enough experimentalist to be able to decide whether to take the claims seriously or not.

The article of Kostadinov provides a detailed support for the claim. Evidence for diamagnetism (induced magnetization tends to reduce the external magnetic field inside superconductor) is represented: at 242 transition reducing the magnitude of negative susceptibility but keeping it negative takes place. Evidence for gap energy of 15 mV was found at 300 K temperature: this energy is same as thermal energy $T/2 = 1.5$ eV at room temperature. Tape tests passing 125 A through superconducting tape supported very low resistance (for Copper tape started burning after about 5 seconds).

I-V curves at 300 K are shown to exhibit Shapiro steps (see http://tinyurl.com/y7qkmubj) with radiation frequency in the range [5 GHz, 21 THz]. Already Josephson discovered what - perhaps not so surprisingly - is known as Josephson effect (see http://tinyurl.com/mo8549n). As one drives super-conductor with an alternating current, the voltage remain constant at certain values. The difference of voltage values between subsequent jumps are given by Shapiro step $\Delta V = hf/Ze$. The interpretation is that voltage suffers a kind of phase locking at these frequencies and alternating current becomes Josephson current with Josephson frequency $f_J = ZeV/h$, which is integer multiple of the frequency of the current. This actually gives a very nice test for $h_{eff} = n\times h$ hypothesis: Shapiro step ΔV should be scaled up by $h_{eff}/h = n$. The obvious question is whether this occurs in the recent case or whether $n = 1$ explains the findings.

The data represented by Figs. 12, 13,14 of [D44] (see http://tinyurl.com/y9hk83ak) suggest $n = 2$ for $Z = 2$. The alternative explanation would be that the step is for some reason $\Delta V = 2hf/Ze$ corresponding to second harmonic or that the charge of the charge carrier is $Z = 1$. I have not been able to find any error in my calculation.

1. Fig 12 shows I-V curve at room temperature T=300 K. Shapiro step is now 45 mV. This would correspond to frequency $f = Ze\Delta V/h = 11.6$ THz. The figure text tells that the frequency is $f_R = 21.762$ THz giving $f_R/f \simeq 1.87$. This would suggest $h_{eff}/h = n \simeq f_R/f \simeq 2$.

2. Fig. 13 shows another at 300 K. Now Shapiro step is 4.0 mV and corresponds to a frequency 1.24 THz. This would give $f_R/f \simeq 1.95$ giving $h_{eff}/h = 2$.

3. Fig. 14 shows I-V curve with single Shapiro step equal to about .12 mV. The frequency should be 2.97 GHz whereas the reported frequency is 5.803 GHz. This gives $f_R/f \simeq 1.95$ giving $n = 2$.

Irrespectively of the fate of the claims of Kostadinov and Eck, Josephson effect could allow an elegant manner to demonstrate whether the hierarchy of Planck constants is realized in Nature.

Room temperature superconductivity for alkanes

Super conductivity with critical temperature of 231 C for n-alkanes containing n=16 or more carbon atoms in presence of graphite has been reported (see http://tinyurl.com/hnefqv9).

Alkanes (see http://tinyurl.com/6pm7mz6) can be linear (C_nH_{2n+2}) with carbon backbone forming a snake like structure, branched (C_nH_{2n+2}, $n \geq 2$) in which carbon backbone splits in one, or more directions or cyclic (C_nH_{2n}) with carbon backbone forming a loop. Methane CH_4 is the simplest alkane.

What makes the finding so remarkable is that alkanes serve as basic building bricks of organic molecules. For instance, cyclic alkanes modified by replacing some carbon and hydrogen atoms by other atoms or groups form aromatic 5-cycles and 6-cycles as basic building bricks of DNA. I have proposed that aromatic cycles are superconducting and define fundamental and kind of basic units of molecular consciousness and in case of DNA combine to a larger linear structure.

Organic high T_c superconductivity is one of the basic predictions of quantum TGD. The mechanism of super-conductivity would be based on Cooper pairs of dark electrons with non-standard value of Planck constant $h_{eff} = n \times h$ implying quantum coherence is length scales scaled up by n (also bosonic ions and Cooper pairs of fermionic ions can be considered).

The members of dark Cooper pair would reside at parallel magnetic flux tubes carrying magnetic fields with same or opposite direction: for opposite directions one would have $S = 0$ and for the same direction $S = 1$. The cyclotron energy of electrons proportional to h_{eff} would be scaled up and this would scale up the binding energy of the Cooper pair and make super-conductivity possible at temperatures even higher than room temperature [K80].

This mechanism would explain the basic qualitative features of high T_c superconductivity in terms of quantum criticality. Between gap temperature and T_c one one would have superconductivity in short scales and below T_c superconductivity in long length scales. These temperatures would correspond to quantum criticality at which large h_{eff} phases would emerge.

What could be the role of graphite? The 2-D hexagonal structure of graphite is expected to be important as it is also in the ordinary super-conductivity: perhaps graphite provides long flux tubes and n-alkanes provide the Cooper pairs at them. Either graphite, n-alkane as organic compound, or both together could induce quantum criticality. In living matter quantum criticality would be induced by different mechanism. For instance, in microtubules it would be induced by AC current at critical frequencies [L22].

How the transition to superconductive state could be induced by classical radiation?

Blog and Facebook discussions have turned out to be very useful and quite often new details to the existing picture emerge from them. We had interesting exchanges with Christoffer Heck in the comment section to "Are microtubules macroscopic quantum systems?" (see `http://tinyurl.com/hwnnfcd`) and this pleasant surprise occurred also now.

Recall that Bandyopadhyay's team claims to have detected the analog of superconductivity, when microtubules are subjected to AC voltage [J9, J42] (see `http://tinyurl.com/ze366ny`). The transition to a state resembling superconductivity would occur at certain critical frequencies. For the TGD inspired model see [L14].

The TGD proposal for bio-superconductivity - in particular that appearing in microtubules - is same as that for high T_c superconductivity [K79, K80]. Quantum criticality, large $h_{eff}/h = n$ phases of Cooper pairs of electrons, and parallel magnetic flux tube pairs carrying the members of Cooper pairs for the essential parts of the mechanism. $S = 0$ ($S = 1$) Cooper pairs appear when the magnetic fields at parallel flux tubes have opposite (same) direction.

Cooper pairs would be present already below the gap temperature but possible super-currents could flow in short loops formed by magnetic flux tubes in ferromagnetic system. AC voltage at critical frequency would somehow induce transition to superconductivity in long length scales by inducing a phase transition of microtubules without helical symmetry to those with helical symmetry and fusing the conduction pathways with length of 13 tubulins associated with microtubules of type B to much longer ones associated with microtubules of type A by the reconnection of magnetic flux tubes parallel to the conduction pathways.

The phonon mechanism responsible for the formation of Cooper pair in ordinary superconductivity cannot be involved with high T_c superconductivity nor bio-superconductivity. There is upper bound of about 30 K for the critical temperature of BCS superconductors. Few days ago I learned about high T_c superconductivity around 500 K for n-alkanes (see `http://tinyurl.com/hwac9e9`) so that the mechanism for high T_c is certainly different [K80].

The question of Christoffer was following. Could microwave radiation for which photon energies are around 10^{-5} eV for the ordinary value of Planck constant and correspond to the gap energy of BCS superconductivity induce phase transition to BCS super-conductivity and maybe to micro-tubular superconductivity (if it exists at all)?

This inspires the question about how precisely the AC voltage at critical frequencies could induce the transition to high T_c - and bio-super-conductivity. Consider first what could happen in the transition to high T_c super-conductivity.

1. In high T_c super conductors such as copper-oxides the anti-ferromagnetism is known to be essential as also 2-D sub-lattice structures. Anti-ferromagnetism suggests that closed flux tubes form of squares with opposite directions of magnetic field at the opposite sides of square. The opposite sides of the square would carry the members of Cooper pair.

2. At quantum criticality these squares would reconnect to very long flattened squares by reconnection. The members of Cooper pairs would reside at parallel flux tubes forming the sides of the flattened square. Gap energy would consists interaction energies with the magnetic fields and the mutual interaction energy of magnetic moments.

   This mechanism does not work in standard QM since the energies involved are quite too low as compared to thermal energy. Large $h_{eff}/h = n$ would however scale up the magnetic energies by n. Note that the notion of gap energy should be perhaps replaced with collective binding energy per Cooper pair obtained from the difference of total energies for gap phase formed at higher temperature and for superconducting phase formed at T_c by dividing with the number of Cooper pairs.

Another important distinction to BCS is that Cooper pairs would be present already below gap temperature. At quantum criticality the conduction pathways would become much longer by reconnection. This would be represent an example about "topological" condensed matter physics. Now hover space-time topology would be in question.

3. The analogs of phonons could be present as transversal oscillations of magnetic flux tubes: at quantum criticality long wave length "magneto-phonons" would be present. The transverse oscillations of flux tube squares would give rise to reconnection and formation of

If the irradiation or its generalization to high T_c works the energy of photon should be around gap energy or more precisely around energy difference per Cooper pair for the phases with long flux tubes pairs and short square like flux tubes.

1. To induce superconductivity one should induce formation of Cooper pairs in BCS superconductivity. In high T_c super-conductivity it should induce a phase transition in which small square shaped flux tube reconnect to long flux tubes forming the conducting pathways. The system should radiate away the energy difference for these phases: the counterpart of binding energy could be defined as the radiated energy per Cooper pair.

2. One could think the analog of stimulated emission (see `http://tinyurl.com/hwac9e9`). Assume that Cooper pairs have two states: the genuine Cooper pair and the non-superconducting Cooper pair. This is the case in high T_c superconductivity but not in BCS superconductivity, where the emergence of superconductivity creates the Cooper pairs. One can of course ask whether one could speak about the analog of stimulated emission also in this case.

3. Above T_c but below gap temperature one has the analog of inverted population: all pairs are in higher energy state. The irradiation with photon beam with energy corresponding to energy difference gives rise to stimulated emission and the system goes to superconducting state with a lower energy state with a lower energy.

This mechanism could explain the finding of Bandyopadhyay's team [J9, J42] that AC perturbation at certain critical frequencies gives rise to a ballistic state resembling superconductivity (no dependence of the resistance on the length of the wire so that the resistance must be located at its ends). The team used photons with frequency scales of MHz, GHz, and THz. The corresponding photon energy scales are about 10^{-8} eV, 10^{-5}, $10{-}2$ eV for the ordinary value of Planck constant and are below thermal energies.

In TGD classical radiation should have also large $h_{eff}/h = n$ photonic counterparts with much larger energies $E = h_{eff} \times f$ to explain the quantal effects of ELF radiation at EEG frequency range on brain [K72]. The general proposal is that h_{eff} equals to what I have called gravitational Planck constant $\hbar_{gr} = GMm/v_0$ [?, K74]. This implies that dark cyclotron photons have universal energy range having no dependence on the mass of the charged particle. Bio-photons have energies in visible and UV range much above thermal energy and would result in the transition transforming dark photons with large $h_{eff} = h_{gr}$ to ordinary photons.

One could argue that AC field does not correspond to radiation. In TGD framework this kind of electric fields can be interpreted as analogs of standing waves generated when charged particle has contacts to parallel "massless extremals" representing classical radiation with same frequency propagating in opposite directions. The net force experienced by the particle corresponds to a standing wave.

Irradiation using classical fields would be a general mechanism for inducing bio-superconductivity. Superconductivity would be generated when it is needed. The findings of Blackman and other pioneers of bio-electromagnetism about quantal effects of ELF em fields on vertebrate brain stimulated the idea about dark matter as phases with non-standard value of Planck constant. The precise mechanism for how this happens has remained open. Also these finding could be interpreted as a generation of superconducting phase by this phase transition.

5.5.7 The implications of TGD view about magnetic fields for superconductivity

TGD predicts two kinds of magnetic fields depending on whether flux tubes carry monopole flux or not. In Maxwellian framework flux tubes cannot carry any monopole flux. In TGD based model of high Tc superconductivity [K79, K80] monopole flux tubes current carriers are dark having nonstandard value $h_{eff} = n \times h_0$ of effective Planck constant. Also in bio-superconductivity monopole flux tubes are current carriers. An open question has been whether also ordinary super-conductivity could correspond to monopole flux tubes and I have considered the possibility that this is the case.

The recent progress in understanding the relationship between two kinds of magnetic fields allows to consider more precisely the relationship between these two kinds of super-conductivities. In particular, one can try to understand Meissner effect in ordinary super-conductivity and its absence in the predicted super-conductivity based on monopole flux tubes. The conclusion is that ordinary super-conductivity corresponds to ordinary flux tubes and that Meissner effect has no counterpart in monopole superconductivity.

It is best to start from the ordinary super-conductivity by making an unpleasant question. Meissner effect (see `http://tinyurl.com/hesedf2`) relates to the possible penetration of magnetic field to super-conductor. Supra-current creates a local magnetic field. Why doesn't this magnetic field destroy super-conductivity?

The answer would be in TGD space-time following.

1. The super-conductor consists of parallel cylindrical tubes carrying supra-currents at their boundaries. These currents create magnetic fields rotating around the cylinders but have no component in z- direction. Magnetic fields vanish at the boundaries of the cylinders.

2. Superconductors can be classified to two types. For superconductors of type I (see `http://tinyurl.com/y4wkzcql`) one has $\lambda/\xi < 1/\sqrt{2}$ whereas for superconductors of type II (see `http://tinyurl.com/y279phzb`) one has $\lambda/\xi > 1/\sqrt{2}$. Here λ is the magnetic penetration length, which is roughly the radius of magnetic flux tube. ξ is the coherence length which is roughly the radius of cylinder carrying supra current at its boundary.

   Supra-current generates vortices and in this manner serves as a source for magnetic field inside magnetic flux tube of field possibly penetrating into superconductor. Flux tube must contain at least one current carrying flux tube. This cannot the case for superconductor of type I. Therefore, when ordinary magnetic field penetrates to super-conductor of type I above critical value of B, it must do so in the entire super-conductor . For superconductor of type II magnetic field can penetrate superconductor of type II in a cylinder of radius of order λ containing several current carrying cylinders. In this region the super-conductivity is destroyed since supra currents have component rotating along the cylinder giving rise to a longitudinal magnetic field inside the cylinder.

What about Meissner effect in monopole superconductors?

1. Monopole flux does not require current as its source. Therefore Meissner effect does not prevent super-conductivity by requiring the super-current to be rotational to generate the magnetic field.

2. Also now the presence of supra current inside monopole flux tube serves as a source for an additional rotational contribution to the magnetic field and the rotor of this additional contribution equals to the supra current. Monopole flux tube is deformed as a consequence. This does not however make supra-current rotational.

   Monopole superconductor can be said to be intermediate between types I and II since both coherence length and magnetic length correspond to flux tube radius. A possible interpretation is that monopole superconductivity is at quantum criticality between superconductivities of type I and II.

3. The most plausible option is that the penetration of ordinary magnetic field to monopole super-conductor occur along non-monopole flux tubes at different space-time sheets so that it would therefore not spoil the super-conductivity at the monopole flux tubes.

5.6 Evidence For Electronic Superconductivity In Bio-Systems

There exists some evidence for super-conductivity in bio-systems. DNA should be insulator but under some circumstances it becomes conductor [I41] and perhaps even high T_c super-conductor. Also evidence for Josephson effect has been reported [D24].

5.6.1 DNA As A Conductor?

Barton *et al* [I41] have done several experiments between 1993-1997 related to the conductivity properties of DNA double helix. The conclusion is that DNA double helix has the ability to do chemistry at distance: *"A DNA molecule with a chemical group artificially tethered to one end appears to mediate a chemical change far down the helix, causing a patch of damaged DNA to be mended."* .

What seems to occur is flow of electron current along DNA with very small resistance. Typically the experiments involve electron donator and acceptor separated by a long distance along DNA. When acceptor is radiated it goes to excited state and an electron current flows from donator to acceptor as a consequence. Standard wisdom tells that this should not be possible. The current should flow by quantum tunnelling between adjacent building units of DNA and it should diminish exponentially with distance. For proteins this is known to be the case. In experiments however no distance dependence was observed. Irradiation with visible light was also involved.

There exist a theory which assumes that the current could flow along the interior of double DNA, that is the region between the bases of strand and complementary strand. The electron would be de-localized in bases rings which would form a stack along DNA. The current would flow by tunnelling also now but the tunnelling probability would be so large that distance dependence would be weak. The critics of Barton argue that this model cannot explain all the experiments of Barton and that the model is not in accordance with basic organic chemistry and biology: ordinary sun light should have rather drastic effects on us. Barton admits that they do not understand the mechanism.

TGD suggests a possible explanation of phenomenon in terms of dark atoms or partially dark atoms for which valence electrons are dark.

1. The bases of DNA contain 5 or 6-cycles: both correspond to Fermat polygons. This symmetry suggests dark phase with $G_a \subset SU(2)$ having maximal cyclic group Z_5 or Z_6 so that one would have $n_a = 5$ or $n_a = 6$ depending on the cycle. This identification would provide first principle explanation for why just these cycles appear in living matter. Most naturally organic atoms would be ordinary but some electrons would reside on dark space-time sheets corresponding to $n_a = 5$ or $n_a = 6$ and $n_b = 1$.

2. The scaled up size of the electronic orbital would be roughly $(n_a n^2/Z_{eff}^2)a_0$ and by a factor n_a^2 larger than the size of ordinary orbital. The large distance of valence electrons suggest $Z_{eff} = 1$ as a first guess, which would imply de-localization of electrons in the length scale $625a_0 \sim 312$ nm for Rb and $900a_0 \sim 45$ nm for Rh. For the estimate $Z_{eff} \sim 10$ deduced below the de-localization would occur in length scales 3 nm and 9 nm which is probably quite enough since there is one DNA triplet per one nanometer if the conduction occurs as a sequence of replacements of a hole with electron analogous to the falling down of domino pieces.

3. The fact that the ratio $6/5 = 1.2$ is rather near to the ratio $45/37 = 1.22$ of nuclear charges of Rh and Rb atoms would guarantee that the binding energy of the valence electron for Rh atom with $n_a = 6$ is reasonably near to that for Rb atom with $n_a = 5$. This encourages to think that the mechanism of conductivity involves the ionization of dark valence electron of acceptor atom so that it can receive the dark valence electron of the donor atom. Delocalization makes this process possible.

4. The DNA environment would induce the phase transition of Rh and Ru atoms to partially dark atoms. The binding energy of the dark valence electron is reduced to $E = (n_b/n_a)^2 Z_{eff}^2 E_0/n^2$, where Z_{eff} is the screened nuclear charge seen by valence electrons, $n = 5$ the principal quantum number for the valence electron in the recent case, and $E_0 = 13.6$

eV the ground state energy of hydrogen atom. $Z_{eff} = 1$ would give.02 eV binding energy which is quite too small. If the binding energy reduces to that of a visible photon parameterized as $E = x$ eV one obtains the condition

$$Z_{eff} = n_a n\sqrt{E/E_0} \simeq 5n_a\sqrt{x/13.6}\ .$$

For Rh $x = 2$ would give $Z_{eff} = 11.5$ and $Z_{eff} = 9.6$ for Rb.

5.6.2 DNA As A Super-Conductor?

Also in the model of ORMEs as dark matter led to $n_a = 6, n_b = 1$ in super-conducting phase. This suggests DNA super-conductivity is based on the same mechanism as the explanation of superconductivity assigned with ORMEs. In particular, the energy $E = .05$ eV associated with the critical potential of neuronal membrane could correspond to the gap energy of the DNA super-conductor and this could relate directly to the activation of DNA. As found, the dark variant of a conventional super-conductor with gap energy around 10 K would give rise to a dark superconductor with a gap energy around room temperature. The estimate $E_g = E/n_a^2$ gives 14 K for $n_a = 6$ and 20 K for $n_a = 5$ for the gap energy. DNA carries -2 units of electric charge per single nucleotide and the interpretation could be as one dark Cooper pair per nucleotide. $n_a = 6$ would give the higher critical temperature.

The fact that there is a twist $\pi/10$ per single nucleotide in DNA double strand led to the proposal that DNA pr RNA might serve as a minimal topological quantum computer with computation based on braiding S-matrix and characterized by $n_a = 5$ [K6]. Perhaps dark Cooper pairs having $n_a = 5$ with charge fractionized to five identical fractions along 5-cycles could relate to the topological quantum computation.

DNA strand and its conjugate could form a pair of weakly coupled super-conductors forming kind of a scaled down version for the pairs formed by the inner and outer lipid layers of the axonal membrane or cell interior and exterior. Both DNA strand and double strand corresponds to the secondary p-adic length scale $L_e(71, 2) \simeq 4.4$ Angstroms. The soliton sequences associated with the phase differences of super-conducting order parameter over the Josephson junctions connecting DNA strands, and idealizable as a continuous one-dimensional Josephson junction, could serve as a quantum control mechanism. Josephson junctions could correspond to MEs which propagate with very low effective phase velocity along the DNA strand. The mathematics would be essentially that of a gravitational pendulum [K82]. Soliton like structures associated with DNA have been proposed also by Peter Gariaev [I45].

Aromatic rings and large $\hbar$ phases

Aromatic rings contain odd number of π de-localized electron pairs with atoms in the same plane. The de-localization of π electrons in the ring is used to explain the stability of these compounds [I1]. Benzene is the classical example of this kind of structure. Delocalization and DNA conductivity suggest interpretation in terms $n_a = 5$ or $n_a = 6$ phase and raises the question whether the de-localization of electrons could occur also in the orthogonal direction and whether it could give rise to Cooper pairs.

Aromatic rings consisting of 5 or 6 carbons are very common in biology. DNA basis have been already mentioned. Carbohydrates consist of monosaccharide sugars of which most contain aromatic ring (glucose used as metabolic fuel are exception). Monoamine neurotransmitters are neurotransmitters and neuromodulators that contain one amino group that is connected to an aromatic ring by a two-carbon chain (-CH2-CH2-). The neurotransmitters known a monoamines are derived from the four aromatic amino acids phenylalanine, tyrosine, histidine, tryptophan. Also norepinephrine, dopamine, and serotonin involve aromatic rings As a rule psychoactive drugs involve aromatic rings: for instance, LSD contains four rings.

These observations inspire the question whether the compounds containing aromatic rings serve as junctions connecting pre- and postsynaptic neurons and induce Josephson currents between them. If Josephson radiation codes for the mental images communicated to the magnetic body, the psychoactive character of these compounds could be understood. One can also ask whether these compounds induce quantum criticality making possible generation of large $\hbar$ phases?

Graphene as another example of dark electron phase?

The behavior of electrons in graphene, which is two-dimensional hexagonal carbon crystal with a thickness of single atomic layer, is very strange [D34]. Electrons behave as massless particles but move with a velocity which is 1/300 of light velocity. Graphene is an excellent conductor. TGD can provide a model for these peculiar properties.

1. One can regard graphene as a giant molecule and the hexagonal ring structure suggests that M^4 Planck constant is scaled up by a factor of 6 and that dark free electron pairs are associated with the ring structures. If also CP_2 Planck is scaled up with the same factor, chemistry is not affected although the size scale of electron wave functions is scaled up by a factor of 6. Just as in the case of DNA, the rings containing de-localized free electron pairs could be responsible for the anomalously high conductivity of graphene. If quantum critical super-conductor is in question, the super-conductivity could become possible in lower temperature.

2. Consider now the explanation for the vanishing of the rest mass. The general mass formula predicted by p-adic thermodynamics [K56] states that particle mass squared is given by the thermal average of the conformal weight and that conformal weight and thus also mass squared is additive in bound states:

$$(\sum_i p_i)^2 = \sum_i m_i^2 \quad (5.6.1)$$

The assumption $p_i^2 = m_i^2$ makes sense only for massless partons moving collinearly. In the QCD based model of hadrons only longitudinal momenta and transverse momentum squared are used as labels of parton states, which would suggest that one has

$$\begin{aligned} p_{i,||}^2 &= m_i^2 \ , \\ -\sum_i p_{i,\perp}^2 + 2\sum_{i,j} p_i \cdot p_j &= 0 \ . \end{aligned} \quad (5.6.2)$$

The masses would be reduced in bound states: $m_i^2 \rightarrow m_i^2 - (p_T^2)_i$. This could explain why massive quarks can behave as nearly massless quarks inside hadrons. In the recent case electrons would become massless if one has hadron like many electron states (free electron pairs?) with $p_T^2 = m_e^2$.

3. TGD also predicts the possibility of anomalous time dilation in the absence of gravitational field implying also reduction of light velocity. The simplest example are vacuum extremals corresponding to the warped embedding $\phi = \omega t$ to $M^4 \times S^1$, S^1 a geodesic sphere of CP_2, which have induced metric for which time component of metric is $g_{tt} = 1 - R^2\omega^2$ instead of $g_{tt} = 1$. Light velocity defined from the time taken to get from point A to B is reduced by a factor $\sqrt{g_{tt}}$ from its maximal value. If the space-time sheets carrying the electrons have $g_{tt} = 1/300$, one can understand the reduction of light velocity.

5.6.3 Conducting DNA And Metabolism

Besides charge transfer also energy transfer along DNA could be of importance in living systems.

Could metabolism involve electronic visible-dark phase transitions at DNA level?

If the dark valence electron associated with an ordinary atom is transformed to ordinary electron, the binding energy of the electron increases which means a liberation of a considerable amount of energy. This phase transition could liberate a large amount of metabolic energy in a coherent manner and might be involved with metabolism at molecular level.

Could the transfer of electrons along DNA make possible energy transfer?

One important function made possible by the assumed dropping of electrons to larger space-time sheets is the transfer of not only charge but also energy through long distances and metabolism might well use this mechanism. The typical energy liberated when ATP molecule is used is about .5 eV. In the model of ATP [K49] it is suggested that energy metabolism involves the circulation of protons between atomic ($k = 137$) space-time sheets and magnetic flux tubes of Earth. The dropping of proton from $k = 137$ atomic space-time sheet to much larger space-time sheet liberates this energy as zero point kinetic energy and generation of ATP molecule involves kicking of three protons back to the atomic space-time sheets by using metabolic energy.

In many-sheeted space-time particles topologically condense at all space-time sheets having projection to given region of space-time so that this option makes sense only near the boundaries of space-time sheet of a given system. Also p-adic phase transition increasing the size of the space-time sheet could take place and the liberated energy would correspond to the reduction of zero point kinetic energy. Particles could be transferred from a portion of magnetic flux tube portion to another one with different value of magnetic field and possibly also of Planck constant h_{eff} so that cyclotron energy would be liberated.

In the following early version of the model assigning metabolic energy quantum to the dropping of protons is considered. In [K80] a model of metabolism associating the metabolic energy quantum to the change of cyclotron energy is discussed.

ATP might provide only the mechanism responsible for the energy transfer over short distances. The dropping of any ion from any space-time sheet to a larger space-time sheet is possible and liberates a definite amount of usable energy. When the smaller space-time sheet corresponds to a super-conducting space-time sheet, the ions or their Cooper pairs can be rapidly transferred as dissipation free supra currents to the region, where the energy is needed. This long distance energy transfer mechanism could be associated with all kinds of linear structures: DNA, proteins, microfilaments, microtubules, axons etc... The magnitude of the energy quantum released would be fixed by the p-adic length scale hypothesis and the mass of the ion or of the Cooper pair. The acceleration in endogenous electric fields provides a mechanism kicking the ions back to the smaller space-time sheets.

Because of their low mass, electrons are exceptional. The dropping of an electronic Cooper pair from $k = 139$ some space-time sheet presumably associated with the hydrogen bonds of length about 3 nm connecting the nucleotides of different DNA strands would liberate a huge energy of about 120 eV. The corresponding UV photon has frequency not far from the miracle frequency associated with $k = 151$ p-adic length scale, which is the first of the four subsequent p-adic miracle length scales corresponding to Gaussian Mersennes. The dropping of electron Cooper pair from the space-time sheet of the DNA strand of thickness of order $4 - 5$ Angstroms, which presumably corresponds to the secondary electron Compton length $L_e(71, 2) \simeq 4.4$ Angstroms, liberates energy of about 15 eV, which in turn corresponds to the p-adic miracle length scale $L_e(157)$. This would mean that all miracle length scales would correspond to some energy unit of energy metabolism [K49] !

An interesting question relates to the possible function of this UV photon. The wavelength $\lambda = L_e(151)$ corresponds to the thickness of the cell membrane. It is also to the minimal length of DNA sequence (10 DNA triplets) with the property that the net winding is a multiple of 2π ($3\times 2\pi$). By its reflection symmetry this helical sequence might serve as a subunit of DNA sequence. The ends of this subunit could act as mirrors connected by MEs carrying Bose-Einstein condensed photons propagating back and worth between the mirrors. The energy liberated by the electron as an UV photon could BE condense to this kind of ME.

At least in the case of monocellulars having DNA at cell membrane, the photon could also be reflected between the outer and inner boundary of the cell membrane.

5.6.4 Some Empirical Evidence For Super Conductivity In Bio-Systems

There is indirect evidence for electronic super conductivity in bio-systems. The basic signatures are photon emission and absorption with energies coming as multiples of the potential difference between two weakly coupled super conductors and voltage-current characteristics of Josephson current. The evidence is related to the tunnelling of electrons between a weakly coupled pair of super conductors.

According to [D10], for several biological systems involving nerve or growth processes the square of the activation energy is a linear function of temperature over a moderate range of physiological temperatures. This behavior may be predicted from the hypothesis that the rate of biological process is controlled by single electron tunnelling between micro-regions of super-conductivity. In TGD framework natural candidates for this kind of regions are the lipid layers of cell membranes and cells themselves.

Positive experimental evidence for Josephson effect is reported and discussed in [D24]. The evidence is based on the observation of voltage-current characteristic typical to the Josephson current flowing between weakly coupled super conductors, which are identified as neighboring cells. Also the radiation of photons with energies which are multiples of the potential difference between the weakly coupled super conductors is used as an empirical signature. The potential difference is about 15 nV and in completely different range as the potential difference of order .05 V between the lipid layers of the cell membrane. Various species of organisms can detect weak magnetic fields from.1 to 5 gauss and this is in accordance with the existence of Josephson junction in systems, which are super conductors of type II in critical region between H_{c_1} and H_{c_2}. The detection of magnetic fields could be based on the same mechanism as the operation of SQUIDs.

5.6.5 Microtubular Space-Time Sheets As Super Conductors?

Microtubules are fashionable candidate for a macroscopic quantum system. Microtubules are the basic structural units of cytoskeleton and it has been suggested that cytoskeleton might play the role of nervous system at single cell level and provide the key element for understanding bio-systems as macroscopic quantum systems [J44]. Microtubules are hollow cylindrical tubes with inner and outer radii of 14 nm and 25 nm respectively so that the thickness of the cylinder corresponds roughly to the length scale $\hat{L}(151)$. Microtubules consist of dimers of α and β tubulines having at least two conformations: the position of electron centrally placed in the α-tubulin-β-tubulin juncture probably determines the conformation. Tubulin dimers have size ~ 8 nm not far from the length scale $\hat{\hat{L}}(157)$. There are 13 columns of tubulin dimers along the microtubule. The skew hexagonal pattern of microbutules exhibits pattern made up of 5 right handed and 8 left handed helical arrangements.

For left handed arrangement 2π rotation corresponds to a distance ~ 64 nm $\sim \hat{L}(163)$ along the length of the microtubule [J70, J8]. It has been suggested [J44] that the electric dipole moments of tubulin dimers form a macroscopic quantum system analogous to a spin system. An alternative possibility is that microtubules might be super conducting. The cylindrical geometry is ideal for the creation of constant magnetic fields inside the tube by helical supercurrents flowing along the surface of the microtubule. The electrons determining the conformation of the tubulin dimer are the most obvious candidates for Cooper pairs. Perhaps the electrons corresponding to a given conformation of tubulin could form de-localized Cooper pairs.

The numbers 5 and 8 correspond to Fermat polygons which suggests that G_a with $n_a = 5 \times 8 = 40$ defining order of maximal cyclic subgroup is involved. $n_a = 40$ was also obtained from the requirement that the 20 amino-acids can be coded by the many-electron states of dark N-hydrogen atom having $n_b = 1$ [K38]. Super-conductivity would correspond to $n_b = 1$ so that by the previous argument the critical temperature would be scaled up by a factor $n_a^2 = 1600$ from that of a conventional super-conductor. The possible problems relate to the thermal stability of light atoms if also nuclei are dark, which is however not expected.

The hypothesis that microtubules are infrared quantum antennas with average length giving rise to .1 eV infrared photon fits nicely with the super conductor idea. The fact that .1 eV is the basic energy scale of wormhole atomic physics explains the average length of microtubules. In case of Cooper pairs there is natural coupling to the Josephson currents related to Josephson junctions between lipid layers of the cell membrane. The coupling of wormhole supra currents to coherent photons contains two contributions. The first contribution is the coupling of the wormhole current to the difference of the gauge potentials describing topologically condensed coherent photons on the two space-time sheets. The second contribution is proportional to the difference of dielectric constants on the two space-time sheets and is non-vanishing even when the topological condensates of coherent photons are identical.

5.6.6 Are Living Systems High T_c Superconductors?

The idea about cells and axons as superconductors has been one of the main driving forces in development of the vision about many-sheeted space-time. Despite this the realization that the supra currents in high T_c superconductors flow along structure similar to axon and having same crucial length scales came as a surprise. Axonal radius which is typically of order $r = .5$ μm. $r = 151 - 127 = 24$ favored by the hypothesis that Mersennes and their Gaussian counterparts defined preferred p-adica length scales and their dark variants would predict $r = .4$ μm. The fact that water is liquid could explain why the radius differs from that predicted in case of high T_c superconductors.

Interestingly, Cu is one of the biologically most important trace elements [D2]. For instance, copper is found in a variety of enzymes, including the copper centers of cytochrome c-oxidase, the Cu-Zn containing enzyme superoxide dismutase, and copper is the central metal in the oxygen carrying pigment hemocyanin. The blood of the horseshoe crab, Limulus polyphemus uses copper rather than iron for oxygen transport. Hence there are excellent reasons to ask whether living matter might be able to build high T_c superconductors based on copper oxide.

What are the preferred values of $\hbar$ for bio-superconductors?

The observed stripes would carry large $\hbar$ electrons attracted to them by hole charge. The basic question concerns the value of $\hbar$ which in the general case is given by $\hbar = x_a x_b$. a refers to CD and b to CP_2. $x_i = n_i$ holds true for singular coverings and $x_i = 1/n_i$ for singular factor spaces. n is is the order of maximal cyclic subgroup $Z_n \subset G$, where G defines singular covering or factor space. Number theoretic vision suggests that the integers n_i, which correspond to a n-polygon constructible using only ruler and compass are physically favored. Thus n_i would be a product containing only different Fermat primes $2^{2^n} + 1$ (3, 5, 17, 257, $2^{16} + 1$) and some power of 2.

The first question concerns the value of the Planck constant assignable to electron.

1. The secondary Compton time scale assignable to the CD of electron is scaled up from $T_e(2, 127) \simeq .1$ seconds (actually fundamental biorhythm) to $rT_e(2, 127)$, $r = \hbar/\hbar_0$. The corresponding p-adic length scale is $\sqrt{r}L_e(127) = \sqrt{r} \times 2.4 \times 10^{-12}$ m.

2. The appearance of 50 meV energy scale which can be interpreted in terms of Josephson energy for cell membrane at criticality for nerve pulse generation is too intriguing signal to be dismissed and forces to ask whether the Compton scales $L_e(k)$, $k = 149, 151$ associated with the lipid layer of cell membrane and membrane itself are involved also with non-biological high T_c super-conductivity.

The model for living matter raises the question whether the favored values of $r = n_a n_b$ correspond to 2^{k_d}, where k_d is difference of integers k_i defining Mersenne primes or Gaussian Mersennes. This hypothesis can be tested.

1. $r = 2^{14}$ $(127-113 = 14)$ would predict effective p-adic length scale $L_e(127+14) = 141) = 3.3$ Angstrom so that dark electrons would have atomic size scale. The thickness of the stripes is few atomic sizes and the members of spin 1 Cooper pair in high T_c super-conductors would naturally have distance given by atomic length scale if they are correspond to nearest neighbors in the lattice. This gives rise to a large Coulomb repulsion between electrons which suggests that the electrons at the magnetic flux tube tend to have as large distance as possible.

2. $r = 2^{24}$ $(151 - 127 = 24)$ would give $L_e(127+24 = 151) = 10nm$ so that dark electron would have size which corresponds to the thickness of the cell membrane. Bio-superconductivity could correspond to this value of $\hbar$. The minimum option is that only the exotic Cooper pairs making possible super-conductivity above T_c and broken by quantum criticality against transition to ordinary electron need have size of order $L_e(151) = 10$ nm. The length of stripes is in the range 1-10 nm and this forces to ask whether this length scale could correspond to the size of Cooper pairs also for high T_c super-conductors.

Neuronal axon as a geometric model for current carrying "rivers"

Neuronal axons, which are bounded by cell membranes of thickness $L_e(151)$ consisting of two lipid layers of thickness $L_e(149)$ are good candidates for high T_c superconductors in living matter.

These flux tubes with radius .4 μm would define "rivers" along which conduction electrons and various kinds of Cooper pairs flow. Scaled up electrons have size $L_e(k_{eff} = 151)$ corresponding to 10 nm, the thickness of the lipid layer of cell membrane. Also the quantum fluctuating stripes of length 1-10 nm observed in high T_c super conductors might relate to the scaled up electrons with Compton length 10 nm, perhaps actually representing zoomed up electrons!

The original assumption that exotic *resp.* BCS type Cooper pairs reside at boundaries *resp.* interior of the super-conducting rivulet. It would however seem that the most natural option is that the hollow cylindrical shells carry all supra currents and there are no Cooper pairs in the interior. If exotic Cooper pairs reside only at the boundary of the rivulet or the Cooper pairs at boundary remain critical against exotic-BCS transition also below T_c, the time dependent fluctuations of the shapes of stripes accompanying high T_c super-conductivity can be understood as being induced by the fluctuations of membrane like structures. Quantum criticality at some part of the boundary is necessary in order to transform ordinary electron currents to super currents at the ends of rivulets. In biology this quantum criticality would correspond to that of cell membrane.

5.7 Exotic Atoms, Wormhole Super Conductivity And Wormhole Magnetic Fields

Exotic atom, wormhole super conductivity and wormhole magnetic fields are purely TGD based concepts and it seems that these concepts might be involved with the transition from organic chemistry to biochemistry. There is certainly much more involved, in particular the long range color and weak forces discussed in [K38].

5.7.1 Exotic Atoms

For ordinary atoms all electrons are condensed on the "atomic" condensation level. One could however think the possibility that some electrons, most probably some valence electrons with high value of principal quantum number n, condense to the lower condensation level, at which atom itself is condensed. This process would give rise to exotic atoms. The exotic counterpart of atom with charge Z would behave chemically as element with $Z - n(val)$, where $n(val)$ is the number of exotic valence electrons. The energy levels of electron at the exotic condensate level should depend only very weakly on the nuclear charge of the parent atom: only the number of valence electrons is what matters. In particular, "electronic" alchemy becomes in principle possible by dropping some electrons on the lower condensate level. One can consider two options depending on whether the dropped electrons are ordinary or dark.

1. Dropped electrons are not dark

The model to be represented is the first version about exotic super-conductivity which was based on the idea about wormhole contact as a counterpart of phonon. Much later it became obvious that charged wormhole contacts can be in fact be identified as counterparts for charged Higgs field making photons massive. This aspect is not discussed below.

The exotic electrons see the Coulomb field of nucleus with effective charge $n(val)$. This charge and gravitational flux flows from the atomic condensate level via the tiny wormhole contacts located near the boundaries of atomic condensate level. If the electric flux of the wormhole is quantized with proton charge as unit there are $n(val)$ wormhole contacts, with each wormhole carrying one unit of electric charge. Note that the minimal unit of flux is naturally 1/3 of elementary charge and the detection of electric flux of this size would be a triumph of the theory. In order to be able to evaluate the energy levels of this pseudo hydrogen atom one must know something about the mass of the wormhole contacts. The following physical considerations give estimate for the mass.

p-Adic length scale hypothesis states that physically most interesting length/mass scales are in one-one- correspondence with p-adic primes p near prime powers of two ($p \simeq 2^k$, k prime) and p-adic mass scale is given by $m \sim 1/L_e(p)$, where $L_e(p)$ is p-adic length scale expressible in terms of Planck length as $L_e(p) \simeq 10^4\sqrt{p}\sqrt{G}$. The representation of wormhole contact as parton pair suggests that apart from effects related to the binding of wormhole throats to single unit, the inertial mass is just the sum of contributions of parton and antiparton associated with the throats carrying opposite gauge quantum numbers. If the time orientations of the space-time sheets involved are opposite, the energies can sum up to zero and the wormhole contact carries no mass. Otherwise the mass is sum of the two masses and the dominant contribution to their mass is determined by the length scale associated with the smaller space-time sheet and thus proportional to $1/\sqrt{p_1}$. In atomic length scales this would give mass of order 10^4 eV and in the length scale corresponding to room temperature mass would be of order 10^{-2} eV. Atoms ($k = 137$) can feed they electromagnetic gauge fluxes directly to "lower" p-adic condensate levels (such as $k = 149$) rather than $k = 139$ to minimize the contribution of wormhole masses to energy.

The small mass of wormhole implies that for atoms with sufficiently high Z it could be energetically favorable to drop electrons to the lower condensate level. Very light wormhole contacts are described by d'Alembert operator associated with the induced metric of the 3-dimensional surface describing the boundary of atomic surface and having one time like direction.

Wormhole contacts are free to move along the boundary of the atomic 3-surface. If wormhole contacts are very light but not exactly massless, it is clear that wormhole contacts behave as bosons restricted to this surface and that state they condense on ground state. For very light but not massless wormhole contacts the lowest state has energy equal to rest mass of the wormhole and next state has energy of order $\pi/a \sim 10^4\ eV$, where a is the radius of atom. Therefore very light wormhole contacts BE condense on the ground state and give rise to a constant charge distribution on the spherical shell surrounding atom. For exactly massless wormhole contacts the zero energy state is not possible and localization of massless wormhole contacts on surface of atomic size would require energy of order $10^4\ eV$. In the interior of this shell electrons are free and in exterior they move in the field of this charge distribution and form bound states. The energies of the electrons at "lower" space-time sheet depend only weakly on the value of Z (only via the dependence of the size of atomic 3-surface on Z) so that the spectral lines associated with the exotic atoms should be in certain sense universal.

The dropping of electrons of heavy atoms, such as Gold or Pb, to the lower space-time sheet, might be energetically favorable or require only a small energy and be induced by, say, absorption of a visible light. Once single electron is dropped it becomes more favorable for second electron to drop since the potential well in the final state is now deeper. The fact, that wormhole contacts form BE Einstein condensate, gives transition probability proportional to N^2 instead of N, N being the number of wormhole contacts already present. In this manner even cascade like process could become possible leading to drop of all valence electrons to the lower space-time sheet. One could even end up from heavy metal such as lead to pseudo-Xenon noble gas evaporating instantaneously!

2. Could exotic valence electrons be dark?

The basic objection against the proposed model is that the proposed wormhole mechanism has no experimental support. If temperature is same at the space-time sheets carrying the dropped electrons, it is not possible to have high T_c super-conductivity for conventional mechanisms.

The valence electrons could however be also dark, which would mean that at some radius atomic electric gauge fluxes flow to a dark space-time sheet and is shared to n_b sub-fluxes so that the each sheet carries flux n_{val}/n_b. For $n_a/n_b > 1$ the fractionization of the radial electric gauge flux could make the states of valence electrons thermally unstable. $n_a/n_b > 1$ would however favor the formation of Cooper pairs and thus high T_c variant of conventional super-conductivity with critical temperature scaled up by n_a^2.

The presence of Ca, Na and K ions in cells and their importance for the functioning of cell membrane could be also due to the fact that these ions are formed when some of the valence electrons transform to dark electrons and become super-conducting. An alternative explanation is that also the nuclei in question are dark and n_a/n_b is so high that atomic binding energies for valence electrons are below thermal threshold and cold plasma of dark ions is formed. These electrons could form Cooper pairs for large enough n_a/n_b. Magnetic flux sheets are excellent candidates for these space-time sheets. The observed ions would result via a phase transition of these ions to ordinary ones. Chemically the resulting elements would behave like noble gas. This kind of mechanism might be involved also with the formation of high T_c super-conductors.

5.7.2 Mono-Atomic Elements As Dark Matter And High T_c Super-Conductors?

The ideas related to many-sheeted space-time began to develop for a decade ago. The stimulation came from a contact by Barry Carter who told me about so called mono-atomic elements, typically transition metals (precious metals), including Gold. According to the reports these elements, which are also called ORMEs ("orbitally rearranged monoatomic elements") or ORMUS, have following properties.

1. ORMEs were discovered and patented by David [H9] [H9] are peculiar elements belonging to platinum group (platinum, palladium, rhodium, iridium, ruthenium and osmium) and to transition elements (gold, silver, copper, cobalt and nickel).
2. Instead of behaving as metals with valence bonds, ORMEs have ceramic like behavior. Their density is claimed to be much lower than the density of the metallic form.
3. They are chemically inert and poor conductors of heat and electricity. The chemical inertness of these elements have made their chemical identification very difficult.
4. One signature is the infra red line with energy of order .05 eV. There is no text book explanation for this behavior. Hudson also reports that these elements became visible in emission spectroscopy in which elements are posed in strong electric field after time which was 6 times longer than usually.

The pioneering observations of David Hudson [H9] - if taken seriously - suggest an interpretation as an exotic super-conductor at room temperature having extremely low critical magnetic fields of order of magnetic field of Earth, which of course is in conflict with the standard wisdom about super-conductivity. After a decade and with an impulse coming from a different contact related to ORMEs, I decided to take a fresh look on Hudson's description for how he discovered ORMEs [H9] with dark matter in my mind. From experience I can tell that the model to be proposed is probably not the final one but it is certainly the simplest one.

There are of course endless variety of models one can imagine and one must somehow constrain the choices. The key constraints used are following.

1. Only valence electrons determining the chemical properties appear in dark state and the model must be consistent with the general model of the enhanced conductivity of DNA assumed to be caused by large $\hbar$ valence electrons with $r = \hbar/\hbar_0 = n$, $n = 5, 6$ assignable with aromatic rings. $r = 6$ for valence electrons would explain the report of Hudson about anomalous emission spectroscopy.
2. This model cannot explain all data. If ORMEs are assumed to represent very simple form of living matter also the presence electrons having $\hbar/\hbar_0 = 2^{k11}$, $k = 1$, can be considered and would be associated with high T_c super-conductors whose model predicts structures with thickness of cell membrane. This would explain the claims about very low critical magnetic fields destroying the claimed superconductivity.

Below I reproduce Hudson's own description here in a somewhat shortened form and emphasize that must not forget professional skepticism concerning the claimed findings.

Basic findings of Hudson

Hudson was recovering gold and silver from old mining sources. Hudson had learned that something strange was going on with his samples. In molten lead the gold and silver recovered but when "I held the lead down, I had nothing". Hudson tells that mining community refers to this as "ghost-gold", a non-assayable, non-identifiable form of gold.

Then Hudson decided to study the strange samples using emission spectroscopy. The sample is put between carbon electrodes and arc between them ionizes elements in the sample so that they radiate at specific frequencies serving as their signatures. The analysis lasts 10-15 seconds since for longer times lower electrode is burned away. The sample was identified as Iron, Silicon, and Aluminium. Hudson spent years to eliminate Fe, Si, and Al. Also other methods such as

Element	Ca	Fe	Si	Al	Pd	Rh
$T_B/^oC$	1420	1535	2355	2327	>2200	2500
Element	Ru	Pt	Ir	Os	Ag	Au
$T_B/^oC$	4150	4300	> 4800	> 5300	1950	2600

Table 5.1: Boiling temperatures of elements appearing in the samples of Hudson.

Cummings Microscopy, Diffraction Microscopy, and Fluorescent Microscopy were applied and the final conclusion was that there was nothing left in the sample in spectroscopic sense.

After this Hudson returned to emission spectroscopy but lengthened the time of exposure to electric field by surrounding the lower Carbon electrode with Argon gas so that it could not burn. This allowed to reach exposure times up to 300 s. The sample was silent up to 90 s after which emission lines of Palladium (Pd) appeared; after 110 seconds Platinum (Pt); at 130 seconds Ruthenium (Ru); at about 140-150 seconds Rhodium; at 190 seconds Iridium; and at 220 seconds Osmium appeared. This is known as fractional vaporization.

Hudson reports the boiling temperatures for the metals in the sample having in mind the idea that the emission begins when the temperature of the sample reaches boiling temperature inspired by the observation that elements become visible in the order which is same as that for boiling temperatures.

The boiling temperatures for the elements appearing in the sample are given by **Table 5.1**.

Hudson experimented also with commercially available samples of precious metals and found that the lines appear within 15 seconds, then follows a silence until lines re-appear after 90 seconds. Note that the ratio of these time scales is 6. The presence of some exotic form of these metals suggests itself: Hudson talks about mono-atomic elements.

Hudson studied specifically what he calls mono-atomic gold and claims that it does not possess metallic properties. Hudson reports that the weight of mono-atomic gold, which appears as a white powder, is 4/9 of the weight of metallic gold. Mono-atomic gold is claimed to behave like super-conductor.

Hudson does not give a convincing justification for why his elements should be mono-atomic so that in following this attribute will be used just because it represents established convention. Hudson also claims that the nuclei of mono-atomic elements are in a high spin state. I do not understand the motivations for this statement.

Remark: More than decade after writing this text (I am writing this 2018) I realized that Hudson's claim about high spin nuclei could make sense in TGD framework. If some valence nucleons inside nucleus, say neutrons in the halo, are dark - just as valence electrons in the model for the findings of Hudson - in the sense of having non-standard value $h_{eff}/h_0 = n$ of Planck constant, the unit for the quantization of angular momentum increases for them. The most plausible identification of the ordinary Planck constant is as $h = 6h_0$ [L26, L37] so that the unit of angular momentum would become $(n/6)\hbar/2$ for these exotic nuclei, and one could understand the large values of nuclear angular momenta.

Claims of Hudson about ORMEs as super conductors

The claims of Hudson that ORMES are super conductors [H9] are in conflict with the conventional wisdom about super conductors.

1. The first claim is that ORMEs are super conductors with gap energy about $E_g = .05$ eV and identifies photons with this energy resulting from the formation of Cooper pairs. This energy happens to correspond one of the absorption lines in high T_c superconductors.

2. ORMEs are claimed to be super conductors of type II with critical fields H_{c1} and H_{c2} of order of Earth's magnetic field having the nominal value $.5 \times 10^{-4}$ Tesla [H9]. The estimates for the critical parameters for the ordinary super conductors suggests for electronic super conductors critical fields, which are about .1 Tesla and thus by a factor $\sim 2^{12}$ larger than the critical fields claimed by Hudson.

3. It is claimed that ORME particles can levitate even in Earth's magnetic field. The latter claim looks at first completely nonsensical. The point is that the force giving rise to the levitation is roughly the gradient of the would-be magnetic energy in the volume of levitating super conductor. The gradient of average magnetic field of Earth is of order B/R, R the radius of Earth and thus extremely small so that genuine levitation cannot be in question.

Minimal model

Consider now a possible TGD inspired model for these findings assuming for definiteness that the basic Hudson's claims are literally true.

1. In what sense mono-atomic elements could be dark matter?

The simplest option suggested by the applicability of emission spectroscopy and chemical inertness is that mono-atomic elements correspond to ordinary atoms for which valence electrons are dark electrons with large value of $r = \hbar/\hbar_0$. Suppose that the emission spectroscopy measures the energies of dark photons from the transitions of dark electrons transforming to ordinary photons before the detection by de-coherence increasing the frequency by r. The size of dark electrons and temporal duration of basic processes would be zoomed up by r.

Since the time scale after which emission begins is scaled up by a factor 6, there is a temptation to conclude that $r = 6$ holds true. Note that $n = 6$ corresponds to Fermat polygon and is thus preferred number theoretically in TGD based model for preferred values of $\hbar$ [K40]. The simplest possibility is that the group G_b is trivial group and $G_a = A_6$ or D_6 so that ring like structures containing six dark atoms are suggestive.

This brings in mind the model explaining the anomalous conductivity of DNA by large $\hbar$ valence electrons of aromatic rings of DNA. The zooming up of spatial sizes might make possible exotic effects and perhaps even a formation of atomic Bose-Einstein condensates of Cooper pairs. Note however that in case of DNA $r = 6$ not gives only rise to conductivity but not super-conductivity and that $r = 6$ cannot explain the claimed very low critical magnetic field destroying the super-conductivity.

2. Loss of weight

The claimed loss of weight by a factor $p \simeq 4/9$ is a very significant hint if taken seriously. The proposed model implies that the density of the partially dark phase is different from that of the ordinary phase but is not quantitative enough to predict the value of p. The most plausible reason for the loss of weight would be the reduction of density induced by the replacement of ordinary chemistry with $r = 6$ chemistry for which the Compton length of valence electrons would increase by this factor.

3. Is super-conductivity possible?

The overlap criterion is favorable for super-conductivity since electron Compton lengths would be scaled up by factor $n_a = 6, n_b = 1$. For $r = \hbar/\hbar_0 = n_a = 6$ Fermi energy would be scaled up by $n_a^2 = 36$ and if the same occurs for the gap energy, T_c would increase by a factor 36 from that predicted by the standard BCS theory. Scaled up conventional super-conductor having $T_c \sim 10$ K would be in question (conventional super-conductors have critical temperatures below 20 K). 20 K upper bound for the critical temperature of these superconductors would allow 660 K critical temperature for their dark variants!

For large enough values of r the formation of Cooper pairs could be favored by the thermal instability of valence electrons. The binding energies would behave as $E = r^2 Z_{eff}^2 E_0/n^2$, where Z_{eff} is the screened nuclear charge seen by valence electrons, n the principal quantum number for the valence electron, and E_0 the ground state energy of hydrogen atom. This gives binding energy smaller than thermal energy at room temperature for $r > (Z_{eff}/n)\sqrt{2E_0/3T_{room}} \simeq 17.4 \times (Z_{eff}/n)$. For $n = 5$ and $Z_{eff} < 1.7$ this would give thermal instability for $r = 6$.

Interestingly, the reported .05 eV infrared line corresponds to the energy assignable to cell membrane voltage at criticality against nerve pulse generation, which suggests a possible connection with high T_c superconductors for which also this line appears and is identified in terms of Josephson energy. .05 eV line appears also in high T_c superconductors. This interpretation does not exclude the interpretation as gap energy. The gap energy of the corresponding BCS super-conductor would be scaled down by $1/r^2$ and would correspond to 14 K temperature for $r = 6$.

Also high T_c super-conductivity could involve the transformation of nuclei at the stripes containing the holes to dark matter and the formation of Cooper pairs could be due to the thermal instability of valence electrons of Cu atoms (having $n = 4$). The rough extrapolation for the critical temperature for cuprate superconductor would be $T_c(Cu) = (n_{Cu}/n_{Rh})^2 T_c(Rh) = (25/36)T_c(Rh)$. For $T_c(Rh) = 300$ K this would give $T_c(Cu) = 192$ K: accoding to Wikipedia cuprate perovskite has the highest known critical temperature which is 138 K. Note that quantum criticality suggests the possibility of several values of (n_a, n_b) so that several kinds of super-conductivities might be present.

ORMEs as partially dark matter, high T_c super conductors, and high T_c super-fluids

The appearance of .05 eV photon line suggest that same phenomena could be associated with ORMEs and high T_c super-conductors. The strongest conclusion would be that ORMEs are T_c super-conductors and that the only difference is that Cu having single valence electron is replaced by a heavier atom with single valence electron. In the following I shall discuss this option rather independently from the minimal model.

1. ORME super-conductivity as quantum critical high T_c superconductivity

ORMEs are claimed to be high T_c superconductors and the identification as quantum critical superconductors seems to make sense.

1. According to the model of high T_c superconductors as quantum critical systems, the properties of Cooper pairs should be more or less universal so that the observed absorption lines discussed in the section about high T_c superconductors should characterize also ORMEs. Indeed, the reported 50 meV photon line corresponds to a poorly understood absorption line in the case of high T_c cuprate super conductors having in TGD framework an interpretation as a transition in which exotic Cooper pair is excited to a higher energy state. Also Copper is a transition metal and is one of the most important trace elements in living systems [D2]. Thus the Cooper pairs could be identical in both cases. ORMEs are claimed to be superconductors of type II and quantum critical superconductors are predicted to be of type II under rather general conditions.

2. The claimed extremely low value of H_c is also consistent with the high T_c superconductivity. The supra currents in the interior of flux tubes of radius of order $L_w = .4$ μm are BCS type supra currents with large $\hbar$ so that T_c is by a factor 2^{14} ($127 - 113 = 14$ is inspired by the Mersenne hypothesis for the preferred p-adic length scales) higher than expected and H_c is reduced by a factor 2^{-10}. This indeed predicts the claimed order of magnitude for the critical magnetic field.

3. The problem is that $r = 2^{14}$ is considerably higher that $r = 6$ suggested by the minimum model explaining the emission spectroscopic results of Hudson. Of course, several values of $\hbar$ are possible so that internal consistency would be achieved if ORMEs are regarded as a very simple form of living matter with relatively small value of r and giving up the claim about the low value of critical magnetic field.

4. The electronic configurations of Cu and Gold are chemically similar. Gold has electronic configuration $[Xe, 4f^{14}5d^{10}]6s$ with one valence electron in s state whereas Copper corresponds to $3d^{10}4s$ ground state configuration with one valence electron. This encourages to think that the doping by holes needed to achieve superconductivity induces the dropping of these electrons to $k = 151$ space-time sheets and gives rise to exotic Cooper pairs. Also this model assumes the phase transition of some fraction of Cu nuclei to large $\hbar$ phase and that exotic Cooper pairs appear at the boundary of ordinary and large $\hbar$ phase.

   More generally, elements having one electron in s state plus full electronic shells are good candidates for doped high T_c superconductors. Both Cu and Au atoms are bosons. More generally, if the atom in question is boson, the formation of atomic Bose-Einstein condensates at Cooper pair space-time sheets is favored. Thus elements with odd value of A and Z

possessing full shells plus single s wave valence electron are of special interest. The six stable elements satisfying these conditions are ^{5}Li, ^{39}K, ^{63}Cu, ^{85}Rb, ^{133}Cs, and ^{197}Au.

2. "Levitation" and loss of weight

The model of high T_c superconductivity predicts that some fraction of Cu atoms drops to the flux tube with radius $L_w = .4$ μm and behaves as a dark matter. This is expected to occur also in the case of other transition metals such as Gold. The atomic nuclei at this space-time sheet have high charges and make phase transition to large $\hbar$ phase and form Bose-Einstein condensate and superfluid behavior results. Electrons in turn form large $\hbar$ variant of BCS type superconductor. These flux tubes are predicted to be negatively charged because of the Bose-Einstein condensate of exotic Cooper pairs at the boundaries of the flux tubes having thickness $L_e(151)$. The average charge density equals to the doping fraction times the density of Copper atoms.

The first explanation would be in terms of super-fluid behavior completely analogous to the ability of ordinary superfluids to defy gravity. Second explanation is based on the electric field of Earth which causes an upwards directed force on negatively charged BE condensate of exotic Cooper pairs and this force could explain both the apparent levitation and partial loss of weight. The criterion for levitation is $F_e = 2eE/x \geq F_{gr} = Am_pg$, where $g \simeq 10$ m^2/s is gravitational acceleration at the surface of Earth, A is the atomic weight and m_p proton mass, E the strength of electric field, and x is the number of atoms at the space-time sheet of a given Cooper pair. The condition gives $E \geq 5 \times 10{-}10Ax$ V/m to be compared with the strength $E = 10^2 - 10^4$ V/m of the Earths electric field.

An objection against the explanation for the effective loss of weight is that it depends on the strength of electric field which varies in a wide range whereas Hudson claims that the reduction factor is constant and equal to 4/9. A more mundane explanation would be in terms of a lower density of dark Gold. This explanation is quite plausible since there is no atomic lattice structure since nuclei and electrons form their own large $\hbar$ phases.

4. The effects on biological systems

Some monoatomic elements such as White Gold are claimed to have beneficial effects on living systems [H9]. 5 per cent of brain tissue of pig by dry matter weight is claimed to be Rhodium and Iridium. Cancer cells are claimed to be transformed to healthy ones in presence of ORMEs. The model for high T_c super conductivity predicts that the flux tubes along which interior and boundary supra currents flow has same structure as neuronal axons. Even the basic length scales are very precisely the same. On basis of above considerations ORMEs are reasonable candidates for high T_c superconductors and perhaps even super fluids.

The common mechanism for high T_c, ORME- and bio- super-conductivities could explain the biological effects of ORMEs.

1. In unhealthy state superconductivity might fail at the level of cell membrane, at the level of DNA or in some longer length scales and would mean that cancer cells are not anymore able to communicate. A possible reason for a lost super conductivity or anomalously weak super conductivity is that the fraction of ORME atoms is for some reason too small in unhealthy tissue.

2. The presence of ORMEs could enhance the electronic bio- superconductivity which for some reason is not fully intact. For instance, if the lipid layers of cell membrane are, not only wormhole-, but also electronic super conductors and cancer involves the loss of electronic super-conductivity then the effect of ORMEs would be to increase the number density of Cooper pairs and make the cell membrane super conductor again. Similar mechanism might work at DNA level if DNA: s are super conductors in "active" state.

5. Is ORME super-conductivity associated with the magnetic flux tubes of dark magnetic field $B_d = 0.2$ Gauss?

The general model for the ionic super-conductivity in living matter, which has developed gradually during the last few years and will be discussed in detail later, was originally based on the assumption that super-conducting particles reside at the super-conducting magnetic flux tubes of Earth's magnetic field with the nominal value $B_E = .5$ Gauss. It became later clear that the explanation of ELF em fields on vertebrate brain requires $B_d = .2$ Gauss rather than $B_E = .5$ Gauss [K37]. The interpretation was as dark magnetic field $B_d = .2$ Gauss. The model of EEG led also to the hypothesis that Mersenne primes and their Gaussian counterparts define preferred p-adic length scales and their dark counterparts. This hypothesis replaced the earlier $r = 2^{11k}$ hypothesis.

For $r = 2^{127-113=14}$ the predicted radius $L_w = .4\ \mu$m is consistent with the radius of neuronal axons. If one assumes that the radii of flux tubes are given by this length scale irrespective of the value of r, one must replace the quantization condition for the magnetic flux with a more general condition in which the magnetic flux is compensated by the contribution of the supra current flowing around the flux tube: $\oint (p - eA) \cdot dl = n\hbar$ and assume $n = 0$. The supra currents would be present inside living organism but in the faraway region where flux quanta from organism fuse together, the quantization conditions $e \int B \cdot dS = n\hbar$ would be satisfied.

The most natural interpretation would be that these flux tubes topologically condense at the flux tubes of B_E. Both bosonic ions and the Cooper pairs of electrons or of fermionic ions can act as charge carriers so that actually an entire zoo of super-conductors is predicted. There is even some support for the view that even molecules and macromolecules can drop to the magnetic flux tubes [K49].

Nuclear physics anomalies and ORMEs

At the homepage of Joe Champion [H25] information about claimed nuclear physics anomalies can be found.

1. The first anomaly is the claimed low temperature cold fusion mentioned at the homepage of Joe Champion. For instance, Champion claims that Mercury (Z=80), decays by emission of proton and neutrons to Gold with Z=79 in the electrochemical arrangement described in [H25].

2. Champion mentions also the anomalous production of Cadmium isotopes electrochemically in presence of Palladium reported by Tadahiko Mizuno.

The simplest explanation of the anomalies would be based on genuine nuclear reactions. The interaction of dark nuclei with ordinary nuclei at the boundary between the two phases would make possible genuine nuclear transmutations since the Coulomb wall hindering usually cold fusion and nuclear transmutations would be absent (Trojan horse mechanism). Both cold fusion and reported nuclear transmutations in living matter could rely on this mechanism as suggested in [K97, L3, K36].

Possible implications

The existence of exotic atoms could have far reaching consequences for the understanding of bio-systems. If Hudson's claims about super-conductor like behavior are correct, the formation of exotic atoms in bio-systems could provide the needed mechanism of electronic super-conductivity. One could even argue that the formation of exotic atoms is the magic step transforming chemical evolution to biological evolution.

Equally exciting are the technological prospects. If the concept works it could be possible to manufacture exotic atoms and build room temperature super conductors and perhaps even artificial life some day. It is very probable that the process of dropping electron to the larger space-time sheet requires energy and external energy feed is necessary for the creation of artificial life. Otherwise the Earth and other planets probably have developed silicon based life for long time ago. Ca, K and Na ions have central position in the electrochemistry of cell membranes. They could actually correspond to exotic ions obtained by dropping some valence electrons from $k = 137$ atomic space-time sheet to larger space-time sheets. For instance, the $k = 149$ space-time sheet of lipid layers could be in question.

The status of ORMEs is far from certain and their explanation in terms of exotic atomic concept need not be correct. The fact is however that TGD predicts exotic atoms: if they are not observed TGD approach faces the challenge of finding a good explanation for their non-observability.

5.7.3 Wormholes And Super-Conductors

Charged wormhole contacts behave like super conductor

Wormhole contacts are bosons and suffer Bose-Einstein condensation to the ground state at sufficiently low temperatures. Their masses are very small and they are mobile in the directions tangential to the surface of atom. Very light but not exactly massless wormhole contacts look therefore ideal candidates for super conducting charge carriers. The em current of wormhole contacts at the "lower" space-time sheet however corresponds to opposite current on the atomic space-time sheet so that actually motion of dipoles is in question (dipole moment is extremely small). Kind of "apparent" super conductivity is in question, which looks real, when one restricts attention to either space-time sheet only. It should be noticed that the dropping of electrons to lower space-time sheets is not absolutely necessarily for wormhole super conductivity since wormhole contacts can appear as genuine particles. For instance, magnetic fields created by rotating wormhole contacts on the boundaries of magnetic flux tubes are possible.

What is required for macroscopic wormhole super conductivity is the formation of a join along boundaries/flux tube condensate at the atomic space-time sheet: JABs would be replaced also with magnetic flux tubes in the case that Kähler does not allow boundaries. This implies that wormhole contacts move freely in the outer surfaces defined by this condensate. Wormhole contacts condense on ground state since there is large energy gap: for very light wormholes and condensate of size L the order of magnitude for the gap is about π/L. Wormhole contacts can appear as super conducting "charge carriers" also at lower condensate levels. The energy gap allows objects with size of order $10^{-5} - 10^{-4}$ meters in room temperature: later it will be suggested that the largest macroscopic quantum systems in brain are of this size. If the thermalization time for between degrees of freedom associated with different space-time sheets is long, wormhole contacts can form metastable BE condensates also in longer length scales.

It has recently become clear that wormhole contacts can be seen as space-time counterparts for Higgs type particles [K56] so that nothing genuinely new would be involved. Coherent states of wormhole contacts could appear also in the description of the ordinary super-conductivity in terms of coherent states of Cooper pairs and charged Higgs type particles making sense in the zero energy ontology [K28]. Mathematically the coherent states of wormholes and Cooper pairs are very similar so that one can indeed speak about wormhole super-conductivity. For instance, both states are described by a complex order parameter. One can of course ask whether charged wormhole contacts and Cooper pairs could be seen as dual descriptions of super-conductivity. This need not be the case since standard Higgs mechanism provides an example of a presence of only wormhole contact Bose-Einstein condensate.

Wormhole magnetic fields as templates for bio-structures?

Wormhole magnetic fields are structures consisting of two space-time sheets connected by wormhole contacts (a more detailed treatment will be found in later chapters). The space-time sheets do not contain ordinary matter and the rotating wormhole contacts near the boundaries of the space-time sheets create magnetic fields of same strength but of opposite sign at the two space-time sheets involved. An attractive possibility is that not only ordinary but also wormhole magnetic fields could correspond to defects in bio super conductors and that they serve as templates for the formation of living matter. DNA and the hollow microtubular surfaces consisting of tubulin molecules are excellent examples of structures formed around defects of type II super conductor. The stripe like regions associated with the defects of superconductor could in turn correspond to wormhole magnetic or Z^0 magnetic fields serving as templates for the formation of cell membranes, epithelial cell sheets and larger structures of same kind.

Super conducting space-time sheets indeed form p-adic hierarchy and same holds true for the sizes of defects characterized by the coherence length ξ in case of super conductors of type II and by the magnetic penetration depth λ in case of super conductors of type I. The assumption that defects correspond to wormhole magnetic fields means that defect is a two-sheeted structure with wormhole magnetic field at larger sheet k cancelling the original magnetic field in the region of defect whereas the upper sheet contains the field as such. If upper sheet k_1 is super-conductor and the penetrating field is below the critical field $B_c(k)$, the field can penetrate only to the sheet k in the region near boundaries of the higher level space-time sheet such that the field strength is so large (by flux conservation) that it exceeds the critical value. This is achieved by the presence of supra currents near the boundaries of the smaller space-time sheet k.

In the case of super conductor of type II penetration occurs as flux tubes in the entire space-time sheet k_1, when the field strength is in the critical range (H_{c_1}, H_{c_2}). This hierarchical penetration in principle continues up to atomic length scales and once can say that defects decompose into smaller defects like Russian doll. It might well be that the fractal structure of defects is a basic architectural principle in bio-systems. Also the amplification of magnetic flux can take place: in this case two sheets contain magnetic fields having opposite directions.

Also defects formed by genuine wormhole magnetic fields are possible: in this case no external field is needed to create the defect. This kind of defects are especially interesting since their 3-space projections need not be closed flux tubes. Topologically these defects are closed as required by the conservation of magnetic flux since the magnetic flux flows from space-time sheet to another one at the ends of the defect behaving like magnetic monopoles.

In the case that the space-time sheets of wormhole magnetic field have opposite time orientations, the particles at the two space-time sheets have opposite inertial energies and it is in principle possible to generate these kind of states from vacuum. A possible interpretation for negative energy particles at the second sheet of the field quantum of wormhole magnetic field is as space-time correlates for holes.

An interesting working hypothesis is that wormhole magnetic fields serve as templates for the formation of bio-structures. The motivations are that defect regions could be regarded as realization for the reflective level of consciousness in terms of fermionic Fock state basis and that the surrounding 3-surface is in super conducting state so that also primitive sensory experiencing becomes possible. One could even say that defects formed by wormhole flux tubes are the simplest intelligent and living systems; that the type of super conductor (I or II) gives the simplest classification of living systems and that systems of type I are at higher level in evolution than systems of type II. A possible example of defects of type II are all linear bio-structures such as DNA, proteins, lipids in the cell membrane, microtubules, etc... Examples of defects of type I would be provided by cell membranes, epithelial sheets and the bilayered structures in the cortex.

How magnetic field penetrates in super conductor?

There are motivations for finding a mechanism for the amplification of magnetic fields although the original motivation coming from attempt to explain the claimed levitation of ORMEs in the Earth's magnetic field has disappeared.

1. Magnetic flux is channelled to flux tubes when it penetrates to super-conductors of type II and the strength of the magnetic field is scaled up roughly as λ/ξ in this process.

2. Cells are known to be sensitive for very weak magnetic fields.

3. TGD proposal for the information storage in terms of topological integers related to magnetic fields also requires that the weak magnetic macroscopic fields prevailing inside brain are somehow amplified to stronger fields in microscopic length scales.

The basic mechanism for the amplification is the current of wormhole contacts induced by external magnetic field at given condensate level, which in turn serves as a source for a secondary magnetic field at higher level. Since the mass of the wormhole contact is very small the resulting current of wormhole contacts and thus the induced secondary magnetic field is strong.

1. The relevant portion of the many sheeted space-time consists of "our" space-time sheet and many sheets above it and at the top is the atomic space-time sheet. At "our" space-time sheet external magnetic field induces em surface current of wormhole contacts at this level. This current is concentrated on 2-dimensional surfaces, which corresponds to the boundaries of 3-surfaces at the previous level of the hierarchy. The interaction of wormhole contacts with the magnetic field is via the vector potential associated with the external magnetic field on "our" sheet. To get rid of unessential technicalities it is useful to assume cylindrical geometry at each space-time sheet: cylindrical surfaces with axis in same direction are considered and the radii of these surfaces get smaller in the higher levels of the topological condensate.

2. Let us study what happens to the wormhole contacts on the cylindrical surface in constant magnetic field in the direction of the cylinder of radius R, when the magnitude of the magnetic field increases gradually. One has to solve d'Alembert type wave equation for the scalar field (describing wormhole contacts on cylinder in the vector potential associated with the external magnetic field, which is constant on the cylinder and in direction of the azimutal coordinate ϕ: $A_\phi = BR/2$. Ground states correspond to the with minimum energy solutions. Vector potential gives just constant contribution to the d'Alembert equation and for small enough values of B the constant, non-rotating solution remains energy minimum. When the condition $eA_\phi = m$, $m = 1, 2, ...$ is satisfied one however gets rotating solution with angular momentum $L_z = m$ with same energy as the original vacuum solution! This implies that at the critical values

$$B_{cr,m} = \frac{(2m+1)}{eR^2} \ , \tag{5.7.1}$$

the solution with $L_z = m$ becomes unstable and is replaced with $L_z = m+1$ to achieve energy minimum.

3. At the higher condensation level the current of wormhole contacts generate a surface current

$$\begin{aligned} K &= n(\#)ev \ , \\ v &= \frac{m}{RE} \ , \end{aligned} \tag{5.7.2}$$

where $n(\#)$ is surface density of the wormhole contacts and $v = R\omega$ is the velocity of rotating wormhole contacts: v is quantized from the quantization of angular momentum. E is the energy of rotating wormhole. This surface current gives rise to axial magnetic field $B = n(\#)ev$ in the interior of the cylinder at the higher condensate level.

4. The magnetic field can penetrate also to the higher levels of the hierarchy via exactly the same mechanism. At higher levels the requirement that magnetic flux is quantized implies relativistic energies for wormhole contacts (see **Fig.** `http://tgdtheory.fi/appfigures/wormholecontact.jpg` or **Fig. ??** in the appendix of this book) and therefore one has $K = n(\#)ev \simeq n(\#)e$. The magnetic fields at various levels have quantized values not depending much on the original magnetic field!

5. In non-relativistic situation one has $v \simeq eBR/m(\#)$ and the relationship $B(higher) = K$ following from Maxwell equations gives

$$\begin{aligned} B(higher) &= \mu_R(p_1,p_2)B(lower) \ , \\ \mu_R(p_1,p_2) &= \frac{e^2 n(\#)R}{m(\#)} \ . \end{aligned} \tag{5.7.3}$$

Non-relativistic wormhole contacts amplify the magnetic field at the larger space-time sheet by a factor $\mu_R(p_1,p_2)$. $\mu_R(p_1,p_2) \sim 10^6$ is required to explain Hudson's claims if penetration takes place in single step: of course multistep process is also possible. It is useful to express the parameters m and R and $n(\#)$ at given p-adic condensation level in terms of the p-adic length scale $L_e(p)$ as

$$\begin{aligned} m(\#) &= \frac{m_0}{L_e(p)} \quad m_0 << 1 \ , \\ R &= R_0 L_e(p) \ , \\ v &= \frac{m}{m_0 R_0} << 1 \ , \\ n(\#) &= \frac{n_0}{L^2(p)} \ . \end{aligned} \tag{5.7.4}$$

By fractality the dimensionless numbers m_0, R_0, n_0. should not depend strongly on p-adic condensation level. The expression for the amplification factor $\mu_R(p_1, p_2)$ in non-relativistic case reads as

$$\mu_R(p_1, p_2) = \frac{e^2 n_0 R_0}{m_0} . \tag{5.7.5}$$

Situation of course becomes relativistic for suitably large values of integer m.

Chapter 6

Bio-Systems as Super-Conductors: Part II

6.1 Introduction

This chapter is devoted to further applications of the theory of high T_c superconductors as quantum critical superconductors involving dark matter hierarchy and large values of h_{eff}. The theory is applied to explain the strange findings about ionic currents through cell membrane, exotic neutrino superconductivity and the notion of cognitive neutrino pair are discussed, and the possibility that superconductivity and Bose-Einstein condensates are involved with atmospheric phenomena is considered.

6.1.1 Strange Behavior Of Cellular Water And Quantal Ionic Currents Through Cell Membrane

The fact that cellular water does not leak out of cell in a centrifugal force suggests that some fraction of water inside cell is in different phase. One explanation is that the nuclei of water inside cell are in doubly dark phase whereas electrons are in singly dark phase (having Compton length of 5 nm and perhaps directly "visible" using recent day technology!) as indeed predicted by the model of high Tc superconductivity. This conceptual framework could explain various findings challenging the notions of ionic pumps.

The empirical findings challenging the notions of ionic pumps and channels, nicely summarized by G. Pollack in his book [I63]. provide a strong support for the notions of many-sheeted space-time and ionic super-conductivity.

1. The selectivity of the cell membrane implies that channels cannot be simple sieves and there must be complex information processing involved.
2. The needed number of pumps specialized to particular ions is astronomical and the first question is where to put all these channels and pumps. On the other hand, if the cell constructs the pump or channel specialized to a given molecule only when needed, how does it know what the pump looks like if it has never seen the molecule? The needed metabolic energy to achieve all the pumping and channelling is huge. Strangely enough, pumping does not stop when cell metabolism stops.
3. One can also wonder why the ionic currents through cell membrane look quantal and are same through cell membrane and silicon rubber membrane.

These observations suggest strongly the presence non-dissipative ionic currents and quantum self-organization. The TGD based explanation would be in terms of high T_c electronic and possibly even ionic superconductivity associated with cell membrane made possible by the large h_{eff} phase for nuclei and electrons in the interior of cell. It however seems that thermal stability conditions allow only protonic Cooper pairs in the model of ionic Cooper pairs based on direct generalization of the model of high T_c electronic super conductivity. This does not however mean that quantal ionic currents would be absent. This empirical input also supports a view about homeostasis as a many-sheeted ionic flow equilibrium controlled by larger space-time sheets with the mediation of massless extremals (MEs) serving as space-time correlates for Bose-Einstein condensates of massless bosons (also of scaled down dark electro-weak bosons and gluons).

In the proposed picture one can understand how extremely low densities of ions and their supra currents can control much higher ion densities at the atomic space-time sheets. The liquid crystal nature of the bio-matter is crucial for the model. This vision allows also much better understanding of the effects of ELF em fields on bio-matter. Also the effects of homeopathic remedies and acupuncture known to crucially involve electromagnetic frequency signatures of chemicals can be understood if homeostasis is based on many-sheeted ionic flow equilibrium.

One can argue that pumps in case of basic ions are needed only when the cell interior and exterior are connected by join along boundaries bonds and that this connection is built only for diagnostic purposes in order to measure the concentrations of ions by measuring the ionic currents by their dissipation. The remote metabolism made possible by many-sheeted lasers reduces further the energy costs when pumping actually occurs. The transfer as Josephson current might apply only to the biologically important ions and pumps might be needed to achieve more efficient transfer also in this case. Pumps (active transport) and channels (passive transport) for more complex polar molecules realized as genetically coded proteins are certainly needed.

How noble gases can act as anesthetes?

Chemically inert noble gases are known to act as anesthetes. Somehow these atoms affect neuronal membrane, probably reducing the nerve pulse activity. A possible explanation is in terms of anomalous weak isospin due to the charged color bonds inside nuclei of noble gas generated in the cellular environment. This bonds carry also em charge so that noble gas atom would behave like ion with nuclear charge Z+1 or Z-1. Also the long ranged color force and dark weak force with range L_w=.2 μm associated with noble gas nuclei in dark phase could be part of the solution of the mystery.

Two models of cell membrane

TGD inspires two views about cell membrane: the wiews need not be contradictory. For the first model cell is far from vacuum extremal, for the second model nearly vacuum extremal with classical Z^0 fields in key role.

1. There are several constraints on the first model coming from the TGD based identification of bio-photons as energy conserving decay products of dark photons and one ends up to a new view about metabolism and gneralization to of the notion of Josephson junction so that Josephson energy includes besides electrostatic energy also the difference of cyclotron energies at two sides of the membrane. It seem that that the first model might be enough when generalized along lines inspired by Pollack's findings about the fourth phase of water.

2. It has been clear from the beginning that the nearly vacuum extremals of Kähler action could play key role key role in living systems. The reason is their criticality making them ideal systems for sensory perception. These extremals carry classical em and Z^0 fields related to each other by a constant factor and this could explain the large parity breaking effects characterizing living matter. The assumption that at least some cell membranes are nearly vacuum extremals and that nuclei can feed their Z^0 charges to this kind of space-time sheets (not true for atomic electrons) in living matter leads to a modification of the model for the cell membrane as Josephson junction. Also a model of photoreceptors explaining the frequencies of peak sensitivity as ionic Josephson frequencies and allowing the dual identifications Josephson radiation as biophotons (energies) and EEG radiation (frequencies) emerge since the values of Planck constant can be very large. Contrary to the original believe, this model does not require non-standard value of Weinberg angle and this model and first model allow a hybrid.

6.1.2 TGD Inspired Model For High T_c Superconductivity

The following minimal model looks the most realistic model of high T_c superconductivity found hitherto. It also applies to ions and if the proposal that h_{eff} is proportional to the mass of ion, it predicts same binding energies for all Cooper pairs as their spin-spin interaction energy. This hypothesis predicts universal spectrum of bio-photons energies if they result from dark photons and is motivated by the identification of gravitational Planck constant [K92] with h_{eff}.

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

2. Usually magnetic field tends to destroy Cooper pairs since it tends to flip the spins of electrons of pair to same direction. In TGD flux quantization comes in rescue and magnetic fields favor the formation of Cooper pairs. If one has two parallel flux tubes with opposite directions of magnetic fluxes with large value of $h_{eff} = nh$, $S = 0$ Cooper pairs with even $L \geq 2$ are favored. This situation is encountered in systems near antiferromagnetic phase transition in small scales leading to formation of sequences of flux loops carrying Cooper pairs. Macroscopic super-conductivity results when the loops are reconnected to two long flux tubes with opposite fluxes. If the magnetic fluxes have same sign, $S = 1$ Cooper pairs with odd $L \geq 1$ are favored.

6.1.3 Hierarchies Of Preferred P-Adic Length Scales And Values Of Planck Constant

TGD inspired quantum biology and number theoretical considerations suggest preferred values for $r = h_{eff}/h$. For the most general option the values of h_{eff} are products and ratios of two integers n_a and n_b. Ruler and compass integers defined by the products of distinct Fermat primes and power of two are number theoretically favored values for these integers because the phases $exp(i2\pi/n_i)$, $i \in \{a, b\}$, in this case are number theoretically very simple and should have emerged first in the number theoretical evolution via algebraic extensions of p-adics and of rationals. p-Adic length scale hypothesis favors powers of two as values of r.

The hypothesis that Mersenne primes $M_k = 2^k - 1$, $k \in \{89, 107, 127\}$, and Gaussian Mersennes $M_{G,k} = (1 + i)k - 1$, $k \in \{113, 151, 157, 163, 167, 239, 241..\}$ (the number theoretical miracle is that all the four p-adic length scales sith $k \in \{151, 157, 163, 167\}$ are in the biologically highly interesting range 10 nm-2.5 μm) define scaled up copies of electro-weak and QCD type physics with ordinary value of h_{eff} and that these physics are induced by dark variants of corresponding lower level physics leads to a prediction for the preferred values of $r = 2^{k_d}$, $k_d = k_i - k_j$, and the resulting picture finds support from the ensuing models for biological evolution and for EEG [K37]. This hypothesis - to be referred to as Mersenne hypothesis - replaces the earlier rather ad hoc proposal $r = h_{eff}/h = 2^{11k}$ for the preferred values of Planck constant.

6.1.4 Bose-Einstein Condensates At Magnetic Flux Quanta In Astrophysical Length Scales

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

1. There are several levels of dynamics. In topological condensation the internal dynamics of ions is unaffected and h_{eff} has the ordinary value. For instance, the formation of Cooper pairs involves dynamics at $k_d = 24 = 151 - 127$ level of dark matter hierarchy if one assumes that electrons and Cooper pairs have size given by the cell membrane thickess $L(151)$. Also

the dynamics of ionic Cooper pairs remains unaffected in the topological condensation to magnetic flux quanta obeying $k_d > 24$ dynamics.

2. Cyclotron energies scale as as h_{eff} so that for a sufficiently high value of k_d thermal stability of cyclotron states at room temperature is achieved for a fixed value of B. Same applies to spin flip transitions in the recent scenario. The model for EEG based on dark matter hierarchy involves the hypothesis that EEG quanta correspond to Josephson radiation with energies in the visible and UV range and that they produce in the decay to ordinary photons either bunches of EEG photons or visible/UV photons. This identification allows to deduce the value of k_d when the frequency of the dark photon is fixed. The Mersenne hypothesis for the preferred p-adic length scales and values of Planck constants leads to very precise predictions.

3. Cyclotron energies $E = (h_{eff}/2\pi) \times ZeB/Am_p$ are scaled up by a factor $r = 2^{k_d}$ from their ordinary values and for 10 Hz cyclotron frequency are in the range of energies of visible light for $k_d = 46$.

4. These B-E condensates might be favored by the large negative spin interaction energies of spins with the magnetic field (proportional to h_{eff}) so that spontaneous magnetization of the magnetic body becomes possible. This kind or process would make possible for the system to gain energy and angular momentum by feeding charged particles to its magnetic body.

6.1.5 Atmospheric Phenomena And Superconductivity

There is a considerable evidence that various electromagnetic time scales associated with the atmospheric phenomena correspond to those associated with brain functioning. If magnetic sensory canvas hypothesis holds true, this is just what is expected. In this section these phenomena are considered in more detail with the aim being to build as concrete as possible a vision about the dynamics involving the dark matter Bose-Einstein condensates at super-conducting magnetic flux quanta, and membrane like structures near vacuum extremals.

In living matter Bose-Einstein condensates of dark matter at magnetic flux quanta near vacuum extremals carrying both em and Z^0 magnetic fields are in fundamental role. Even neutral atoms with net weak isospin spin which is non-vanishing for nuclei for which proton and neutron numbers are different, couple to the classical Z^0 field so that a plasma like state would be in question.

Tornadoes and hurricanes provide the first example of self-organizing systems which might also correspond to systems for which some space-time sheets are near vacuum extremals. Auroras represent a second phenomenon possibly involving supra currents of Cooper pairs and of exotic ions. Lightnings, sprites and elves might also involve higher levels of dark matter hierarchy. p-Adic length scale hypothesis and the hierarchy of Planck constants provide a strong grasp to these far from well-understood phenomena and allow to build rather detailed models for them as well as to gain concrete understanding about how dark matter hierarchy manifests itself in the electromagnetic phenomena at the level of atmosphere.

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 [L13].

6.2 Empirical Support For Ionic Super-Conductivity As A Fundamental Control Mechanism

The notions of ionic channels and pumps associated with cell membrane are central for the standard cell biology [I87]. There are however puzzling observations challenging this dogma and suggesting that the currents between cell interior and exterior have quantum nature and are universal in the sense that they not depend on the cell membrane at all [I64, I53, I36, I97, I52]. One of the pioneers in the field has been Gilbert Ling [I64], who has devoted for more than three decades to the problem, developed ingenious experiments, and written several books about the topic. The introduction of the book [I63]) gives an excellent layman summary about the paradoxical experimental results[1].

It was a pleasant surprise to find that these experimental findings give direct support for the role of supercurrents and Josephson currents in biocontrol. In fact, the experimental data lead to an archetype model cell homeostasis as a flow equilibrium in which very small densities of super-conducting ions (also molecular ions) and ionic supercurrents at cellular and other super-conducting space-time sheets dictate the corresponding densities at the atomic space-time sheets. Z^0 super-conductivity in principle allows to generalize the model also to the control of the densities of neural atoms and molecules at atomic space-time sheets.

6.2.1 Strange Behavior Of The Intracellular Water

The basic strange feature of cellular interior is related to its gelatinous nature and is in fact familiar for everyone. Although 80 percent of hamburger is water, it is extremely difficult to extract this water out. Ling [I53] has demonstrated this at cellular level by using a centrifuge and cells for which cell membrane is cut open: centrifugal accelerations as high as 1000 g fail to induce the separation of the intracellular water.

The dipolar nature of biomolecules and induced polarization are basis prerequisites for the formation of gels. Ling raises the cohesion between water and protein molecules caused by electric dipole forces as a fundamental principle and calls this principle association-induction hypothesis [I64]. This cohesion gives rise to liquid [F13] [D4] like structure of water implying among other things layered structures and internal electric fields orthogonal to the plane of the layers [I76, I67, I64]. For instance, cell membranes can be understood as resulting from the self-organization of liquid crystals [K23]. The fundamental importance of electret nature of biomatter was also realized by Fröhlich [I66] and led him to suggest that macroscopic quantum phases of electric dipoles might be possible. This concept, which is in central role in many theories of quantum consciousness, has not been established empirically.

6.2.2 Are Channels And Pumps Really There?

Standard neurophysiology relies strongly on the concepts of what might be called hydro-electro-chemistry. The development of the theory has occurred through gradual improvements saving the existing theory.

The development began from the basic observation that cells are stable gelatinous entities not mixing with the surrounding water. This led to the hypothesis that cell membrane takes care that the contents of the cell do not mix with the cell exterior. It was however soon found that cell membrane allows some ions to flow through. The interaction between theory and experiment led gradually to the notions of ion channel and ion pump, which are still central for the standard paradigm of the cell [I87]. Note that also "electric pump" taking care that membrane potential is preserved, is needed.

These notions developed gradually during the period when cell was seen as a bag containing water and a mixture of various biochemicals. If cell biology would have started to develop during the latter half of this century and after the discovery of DNA, cell as a computer metaphor might have led to a quite different conceptualization for what happens in the vicinity of the cell membrane. Also the notion of liquid crystals [D4] would have probably led to different ideas about how homeostasis between cell interior and exterior is realized [I76, I67, I64].

For me it was quite a surprise to find that pump-channel paradigm is not at all so well-established as I had believed as an innocent and ignorant outsider. The first chapter of the book "Cells, Gels and the Engines of Life" of Gerald Pollack [I63] provides a summary about the experimental paradoxes (the interested reader can find the first chapter of this book from web).

The standard theoretical picture about cell is based on the observation that cell exterior and interior are in a relative non-equilibrium. The measured concentrations of various atomic ions and organic molecules are in general different in the interior and exterior and cell membrane seems to behave like a semi-permeable membrane. There is also a very strong electric field over the cell membrane. In standard approach, which emerged around 1940, one can understand the situation

[1]I am grateful for "Wandsqueen" for sending me the relevant URL address and for Gene Johnson for very stimulating discussions.

by assuming that there are cell membrane pumps pumping ions from cell interior to exterior or vice versa and channels through which the ions can leak back. Quite a many candidates for proteins which seem to function like pump and channel proteins have been identified: even a pump protein for water [I63] ! This does not however prove that pumping and channelling is the main function of these proteins on the case of basic biological ions or that they have anything to do with how ionic and molecular concentrations in the interior and exterior of the cell are determined. It could quite well be that in the case of basic ions pump and channel proteins are receptors involved with the transfer of information rather than charges and only effectively act as pumps and channels.

There are several serious objections of principle against the vision of cell as a bag of water containing a mixture of chemicals. Even worse, the hypothesis seems to be in conflict with experimental data.

Selectivity problem

Cell membrane is extremely selective and this leads to an inflation in the complexity of channels and pumps. The problem might be christened as a dog-door problem: the door for dog allows also cat go through it. Channels cannot be simple sieves: it is known that channels which let some ions through do not let much smaller ions through. There must be more complicated criteria than geometric size for whether the channel lets the ion go through. Quite generally, channels must be highly selective and this seems to require complicated information processing to decide which ion goes through and which not. As a consequence, the models for channels inflate in their complexity.

The only reasonable way to circumvent the problem is to assume that there is kind of binary coding of various chemical compounds but it is difficult to see how this could be achieved in the framework of the standard chemistry. The notion of fractional atom proposed in [K38] to give rise to the emergence of symbols at the level of biochemistry could however allow this kind of coding. Channels and pumps (or whatever these structures actually are) could be also generated by self-organization process when needed.

Inflation in the number of pumps and channels

Channels and pumps for atomic ions and channels and pumps for an astronomical number of organic molecules are needed. The first question is where to put all those channels and pumps? Of course, one could think that pumps and channels are constructed by the cell only when they are needed. But how does the cell know when a new pump is needed if the cell as never met the molecule in question: for instance, antibiotic or curare molecule?

To realize how weird the picture based on channels and pumps is, it is useful to imagine a hotel in which there is a door for every possible client letting only that client through but no one else. This strange hotel would have separate door for every five point five milliard humans. Alternatively, the building would be in a continual state of renovation, new doors being built and old being blocked.

There is however an TGD based objection against this slightly arrogant argument. In TGD framework cell is a self-organizing structure and it might be that there is some mechanism which forces the cell to produce these pumps and channels by self-organization. Perhaps the basic characteristic of quantum control in many-sheeted space-time is that it somehow forces this kind of miracles to occur.

Why pumping does not stop when metabolism stops?

One can also wonder how metabolism is able to provide the needed energy to this continual construction of pumps and channels and also do the pumping. For instance, sodium pump alone is estimated to take 45-50 per cent of the cell's metabolic energy supply. Ling has studied the viability of the notion of the ionic pump experimentally [I64] by exposing cell to a coctail of metabolic poisons and depriving it from oxygen: this should stop the metabolic activities of the cell and stop also the pumping. Rather remarkably, nothing happened to the concentration gradients! Presumably this is the case also for the membrane potential so that also the notion of metabolically driven electrostatic pumps seems to fail. Of course, some metabolism is needed to keep the equilibrium but the mechanism does not seem to be a molecular mechanism and somehow manages to use extremely small amount of metabolic energy.

How it is possible that ionic currents through silicon rubber membrane are similar to those through cell membrane?

A crucial verification of the channel concept was thought to come in the experiment of Neher and Sakmann [I98] (which led to a Nobel prize). The ingenious experimental arrangement was following. A patch of membrane is sucked from the cell and remains stuck on the micropipet orifice. A steady voltage is applied over the patch of the membrane and the resulting current is measured. It was found that the current consists of discrete pulses in consistency with the assumption that a genuine quantum level current is in question. The observation was taken as a direct evidence for the postulate that the ionic currents through the cell membrane flow through ionic channels.

The later experiments of Fred Sachs [I97] however yielded a complete surprise. Sachs found that when the patch of the cell membrane was replaced by a patch of silicon rubber, the discrete currents did not disappear: they remained essentially indistinguishable from cell membrane currents! Even more surprisingly, the silicon rubber membrane showed ion-selectivity features, which were essentially same as those of the cell membrane! Also the currents through synthetic polymer filters [I52] were found to have essentially similar properties: as if ion selectivity, reversal potential, and ionic gating would not depend at all on the structure of the membrane and were more or less universal properties. Also experiments with pure lipid-layer membranes [I36] containing no channel proteins demonstrated that the basic features – including step conductance changes, flickering, ion selectivity, and in-activation– characterized also cell membranes containing no ionic channels.

The in-escapable conclusion forced by these results seems to be that the existing 60-year old paradigm is somehow wrong. Ionic currents and the their properties seem to be universal and depend only on very weakly on the properties of the membrane. This conclusion need not apply to the currents of polar molecules for which genetically coded pump and channel proteins certainly exists. Neither does it imply that pumps and channels could not be used to achieve a more efficient transfer of ions. Pump - and channel proteins seem to be a well-established notion and TGD approach suggests that they serve as Josephson junctions.

This however requires a generalization of the ordinary thermodynamical approach to cell membrane by starting from zero energy ontology and replacing Boltzmann weight with the complex square roots. Chemical potentials giving dominant part to the change of energy as it goes through cell membrane is replaced with the difference of cyclotron energy which is in visible and UV range from the condition that dark EEG photons have energies of bio-photons [K37]. One ends up with a generalization of Josephson junction: the generalized Josephson energy includes besides Coulombic energy difference also the cyclotron energy difference. Dark cyclotron contribution raises the energy scale of.05-.1 eV associated with cell membrane to.5-10 eVs and one can understand the nominal value.5 eV of metabolic energy currency.

6.2.3 Could The Notion Of The Many-Sheeted Space-Time Solve The Paradoxes?

The basic paradoxes are related to the universality of the ionic currents challenging the notion of ionic channels and the absence of metabolically driven chemical pumps assignable to cell membrane. Chemical pumps take care that the differences of the chemical potentials associated with the two sides of the cell membrane remain non-vanishing just like ordinary pump preserves a constant pressure difference. Also "electrical pump" taking care that the potential difference between the cell exterior and interior is preserved is needed. The experiments suggest strongly that both chemical pumps and "electrical pump", if present at all, need very low metabolic energy feed.

Many-sheeted space-time (see **Fig.** `http://tgdtheory.fi/appfigures/manysheeted.jpg` or **Fig.** 9 in the appendix of this book) allows following interpretation for the puzzling findings.

1. What have been identified as pumps and channels are actually ionic receptors allowing the cell to measures various ionic currents flowing through membrane.

2. Pumps are not needed because the cell interior and exterior correspond to disjoint space-time sheets. The currents run only when flux tube (JAB) is formed and makes the current flow possible. The fact that the formation of JABs is quantal process explains the quantal nature of the currents. Channels are not needed because the currents run as supercurrents (also

the cyclotron states of bosonic ions define Bose-Einstein condensates) along cell membrane space-time sheet. The absence of dissipation would explain why so little metabolic energy feed is needed and why the ionic currents are not changed when the cell membrane is replaced by some other membrane. JABs could be formed between the space-time sheets representing lipid layers or between cell exterior/interior and cell membrane space-time sheet. The formation of JABs has also interpretation as a space-time correlate for the generation of quantum entanglement.

Note that the most recent TGD view about JABs differs from the original one. The recent belief is that boundaries- and jus JABs- are not allowed by the boundary conditions: space-time sheets with boundary are replaced with their double covers. Furthermore, elementary particles and also larger systems correspond to space-time regions which as lines of generalized Feynman diagrams have Euclidian signature of the induced metric. This suggests that magnetic flux tubes as deformations of cosmic strings have Euclidian signature of metric too. This is quite possible and in the simplest situation would require that string world sheet has Euclidian signature of the induced metric. JABs in this sense would serve as correlates of quantum entanglement between system that they connect together.

Double cover property means that JABs identified as Kähler magnetic flux tubes have cross section, which are closed surfaces, and thus can carry quantized Kähler magnetic flux. These flux tubes would provide correlates for the magnetic fields known to exist in cosmological scales but no possible in standard cosmology due to the fact that needed currents should be coherent in long scales. For monopole fluxes no currents are needed.

3. The universality of the currents suggests that the densities of current carriers are universal. The first interpretation would be in terms of a ordinary-dark-ordinary phase transition. Ordinary charge carriers at space-time sheets associated with cell interior and exterior would be transformed to dark matter particles at the cell membrane space-time sheet and flow through it as supercurrents and then transform back to ordinary particles (reader is encouraged to visualize the different space-time sheets). This phase transition could give for the currents their quantal character instead of the formation of JABs. Of course, the formation of JABs might be prerequisite for this phase transition.

4. The ion densities in cell interior and exterior are determined by flow equilibrium conditions for currents traversing from super-conducting space-time sheets to non-super-conducting space-time sheets and back. Ion densities would be controlled by super-conducting ion densities by an amplification mechanism made possible by the electret nature of the liquid crystal state. The dissipation by the currents at the atomic space-time sheets associated with cell interior and exterior is very weak by the weakness of the electric fields involved and at cell membrane space-time sheet superconductivity means absence of dissipation.

One must of course be cautious in order to not draw too strong conclusions. Besides basic ions cell membrane is non-permeable to various polar molecules such as the basic building bricks of DNA and amino-acids. The safest assumption is that genetically coded pump and channel proteins make possible the transfer. One must of course consider the possibility that channels and pumps are used to make the transfer of basic ions more effective. Taking this into account, the proposed vision does not differ so radically from the standard one as one might think first and only the model for nerve pulse generation must be modified radically.

Many-sheeted cell

TGD based model of nerve pulse and EEG relies on the notion of the many-sheeted space-time. There is entire hierarchy of space-time sheets so that one can assign to cell and its exterior atomic space-time sheets forming join-along boundaries condensate of units of size of about 10^{-10} meters, lipid layer *resp.* cell membrane space-time sheets with thickness of order $L(149) \simeq .5 \times 10^{-8}$ meters *resp.* $L(151) \simeq 10^{-8}$ meters, and cellular space-time sheets with size of order few microns. These space-time sheets are certainly not the only ones but the most important ones in the model of EEG and nerve pulse.

1. Water molecules at the atomic space-time sheet can form flux tube condensates and the strange properties of water inside the cell can be understood if these lumps in the cell interior have size larger than the flux tubes connecting atomic space-time sheet of cell interior to that of cell exterior. Liquid crystal structure indeed gives rise to layered crystal like structures of water.

2. Cell membrane space-time sheets have size of order cell membrane thickness and are assumed to be super-conducting. The lipid layers of the cell membrane define space-time sheets of thickness of about 50 Angstrom, which could act as parallel super-conductors connected by Josephson junctions.

3. Cellular space-time sheets have size of order cell size and are multi-ion super-conductors. Also they are connected to each other by flux tubes serving as Josephson junctions. Also charged organic molecules could form super-conductors and be transferred by the same mechanism between cell interior and exterior. In TGD framework also classical Z^0 fields are present and Z^0 super-conductivity is possible and could make possible neutral supra currents and control of the densities of the neutral atoms and molecules.

Neuronal and cellular space-time sheets of size of order cell size are assumed to be parts of the magnetic flux tube like structures associated with Earth's magnetic field. Earth's magnetic field inside organisms could contain closed circuits and it is conceivable that the notion of magnetic circulation containing neural circuitry as a sub-circuitry makes sense. Large value of $\hbar$ makes possible high T_c superconductivity. Only protonic Cooper pairs are possible at room temperature besides electronic and neutrino Cooper pairs using the proposed criterion super conductivity. Bose-Einstein condensates of bosonic ions at cyclotron states define also superconductors and at $k = 4$ level of dark matter hierarchy the cyclotron frequencies in Earth's magnetic field correspond to energies above thermal energy. These frequencies are in alpha band for most biologically relevant bosonic ions.

Electronic Josephson currents through cell membrane oscillate with a frequency which is given by the membrane potential $eV = 70\ meV$: this predicts that the emission of infrared photons as a signature of a living cell. Super currents transform to Ohmic currents when they enter to the atomic space-time sheets.

Also present are "many-sheeted circuits" for which currents flow along super-conducting space-time sheets go to atomic space-time sheets where they flow as very weak Ohmic currents, and run back to super-conducting space-time sheets. The currents flowing in closed circuits traversing both cellular and atomic space-time sheets are in flow equilibrium. Because of the high value of the cell membrane electric field, the ionic currents flowing at cell membrane space-time sheets would give rise to high dissipation. The ohmic currents from the cell exterior to interior can however enter to the super-conducting cell membrane space-time sheet and back to the atomic space-time sheet of the cell interior and thus avoid the dissipation.

This picture suggests that the flow of particles between the cell interior and exterior takes mainly via the cell membrane space-time sheet. This would mean that $k = 169$ cell interior space-time sheet has permanent bridges to the $k = 151$ cell membrane space-time sheet, which in turn has only temporary bridges to the $k = 169$ cell exterior space-time sheets.

The character of the ionic currents through cell membrane is highly relevant for the model of the nerve pulse. The development of the model of nerve [K82] [K82] has taken a long time and the original hypothesis about the decisive role of the ionic Josephson currents turned out to be wrong. The recent version of the model assumes that the reduction of charge entanglement between magnetic body and neuron interior made possible by charged W MEs leads to a exotic ionization of the Ca^{++} Bose-Einstein condensate. Exotic $Ca^{++,+}$ Bose-Einstein condensate reduces the membrane resting potential below the threshold for the generation of nerve pulse. The random generation of JABs makes possible flow of ionic currents and leads to the generation of nerve pulse. One cannot exclude the possibility that a portion of em or Z^0 ME drifting along the axon with the velocity of nerve pulse and connecting cell exterior and cell membrane space-time sheets defines the JAB: in the earlier version of the model Z^0 ME was responsible for the reduction of the membrane potential.

Faraday's law of induction in the many-sheeted space-time forces electrical non-equilibrium

Faraday's induction law in many-sheeted space-time gives strong constraints on the electric fields over the cell membrane region at various space-time sheets. Suppose that cellular space-time sheet and some other space-time sheets, say cellular and cell membrane space-time sheet, are in contact so that one can form a closed loops traversing along both space-time sheets. Faraday's law implies that the rotation of electric field around a closed loop traversing first from cell exterior to interior at cellular space-time sheet, going to the atomic space-time sheet and returning back to cell exterior and down to cellular space-time sheet must be equal to the time derivative of the magnetic flux through this loop. Since magnetic flux cannot grow indefinitely, the time average of this potential difference is vanishing. During the generation of nerve pulse the situation might change but only for a finite duration of time (of order millisecond).

Thus in electrostatic equilibrium there must be same exterior-interior potential difference over all space-time sheets in contact with cellular space-time sheets and the variation of potential difference at cellular space-time sheets induces automatically an opposite variation at other space-time sheets. This means that the supercurrents at cellular space-time sheets can indeed control potential differences at other space-time sheets, in particular at atomic space-time sheets. Faraday's law in the many-sheeted space-time also implies that Ohmic currents at atomic space-time sheets cannot destroy the potential difference except for a finite period of time.

Faraday's law makes also possible a gauge interaction between dark and ordinary matter. The changes of dark matter charge densities induce changes of electric field patterns at dark matter space-time and once JABs are formed between dark matter space-time sheet and space-time sheets at lower level of dark matter hierarchy, closed many-sheeted circuits become possible and voltage differences along space-time sheet at different levels of dark matter hierarchy correspond to each other.

Massless extremals (MEs, topological light rays) serve as correlates for dark bosons. Besides neutral massless extremals (em and Z^0 MEs) TGD predicts also charged massless extremals obtained from their neutral counterparts by a mere color rotation (color and weak quantum numbers are not totally independent in TGD framework). The interpretation of the charged MEs has remained open hitherto. Charged W MEs could induce long length scale charge entanglement of Bose-Einstein condensates by inducing exotic ionization of ionic nuclei. State function reduction could lead to a state containing a Bose-Einstein condensate in exotically ionized state.

In this manner the charge inside neuron and thus by Faraday's law membrane potential could be affected by magnetic body. The generation of nerve pulse could rely on the reduction of the resting potential below the critical value by this kind of mechanism inducing charge transfer between cell interior and exterior. The mechanism might apply even in the scale of magnetic body and make possible the control of central nervous system. Also remote mental interactions, in particular telekinesis, might rely on this mechanism.

Flow equilibrium in many-sheeted space-time

The notion of many-sheeted space-time suggests that cell interior and exterior could be regarded as a system in "many-sheeted flow equilibrium" so that the ion densities at atomic space-time sheets are determined by the ion densities at the super-conducting cellular space-time sheets and by the drift velocities by the basic formula $n_1/n_2 = v_2/v_1$ for flow equilibrium.

1. Cell exterior and interior understood as many-sheeted structures are in ionic flow equilibrium holding true for each ion type. The ionic currents run along circuits which traverse along super-conducting space-time sheets, enter into atomic space-time sheets and back to super-conducting space-time sheets.

2. To understand what is involved consider the simplest possible closed circuit connecting atomic and cellular space-time sheets. The ionic supercurrent $I_{i,s}$ flowing from a super-conducting space-time sheet to the atomic space-time sheet is transformed to Ohmic current $I_{i,O}$ in the atomic space-time sheet and in flow equilibrium one has

$$I_{i,s}(int) = I_{i,s} = I_{i,O}(ext) = I_i(membr) \ .$$

3. Ionic supra curent is sum of two terms.

$$I_{i,s} = I_{i,s|J} + I_{i,s|d} \ .$$

The first term is the oscillatory Josephson current associated with the Josephson junction connecting interior and exterior cellular space-time sheet. The second term is direct super-current

$$I_{i,s|d} = \frac{1}{m_i} n_{i,s} \nabla\phi = \frac{n_{i,s} K_i}{m_i} \ ,$$

where ϕ is the phase of the super-conducting order parameter, and m_i is the mass of the ion. K_i is the quantized momentum like quantum number associated of superconducting loop (assuming for simplicity that current is constant).

4. Ionic Ohmic current is equal to

$$I_{i,O}(int) = \frac{n_i(int) q_i E_{int}}{k_i(int)} \ ,$$

$$I_{i,O}(ext) = \frac{n_i(ext) q_i E_{ext}}{k_i(ext)} \ .$$

Here k_i is linear friction coefficient. Since cell exterior and interior are in different internal states, k_i is different for cell interior and exterior. E is the weak internal electric field made possible by liquid crystal property which is also different for the interior and exterior. Flow equilibrium conditions give for the ratio of the ion densities in interior and exterior

$$\frac{n_i(int)}{n_i(ext)} = \frac{v_i(ext)}{v_i(int)} = \frac{E_{ext}}{E_{int}} \frac{k_i(int)}{k_i(ext)} \ .$$

Thus in flow equilibrium the ratio of the internal and external ion densities differs from unity and is determined by the ratio of the ionic drift velocities, which are different in cell interior and exterior.

5. The densities of the super-conducting ions at super-conducting space-time sheet determine the corresponding ion densities at the atomic space-time sheet

$$\frac{n_i(int)}{n_{i,s}} = \frac{v_{i,s}}{v_i(int)} = \frac{K_i k_i(int)}{m_i E_{int}} \ ,$$

$$\frac{n_i(ext)}{n_{i,s}} = \frac{v_{i,s}}{v_i(ext)} = \frac{K_i k_i(ext)}{m_i E_{ext}} \ .$$

Obviously, super-conducting ion densities control the ion densities at the atomic space-time sheets. Very weak electric fields E_{ext} and E_{int} and high values of friction coefficients k_i make possible a large amplification of the superconducting densities to the non-super-conducting ionic densities at atomic space-time sheet. Thus the fact that liquid crystals allowing weak but stable electric fields orthogonal to the layer like structure is crucial for the mechanism.

6. Also flow equilibrium requires metabolism to keep the currents at the atomic space-time sheets flowing. There are two options.
i) Assuming that the current flows through cell membrane as an Ohmic current, the power dissipated in the circuit is equal to

$$P = I_i(int)(V_{int} + V_{memb} + V_{ext}) = I_{i,s}(V_{int} + V_{memb} + V_{ext}) \ .$$

Since supercurrents and thus also Ohmic currents are weak and electric fields are weak in cell interior and exterior, also dissipation can be extremely low in these regions. The dominating and problematic term to the dissipation comes from the membrane potential which is very large.
ii) An alternative option is that the current flows flows through cell membrane region as a

supercurrent by going from atomic to cell membrane space-time sheet and returning back to atomic space-time sheet. This gives

$$P = I_{i,s}(V_{int} + V_{ext}) \ .$$

In this manner huge amount of metabolic energy would be saved and it is quite possible that this is the only sensical manner to understand the experimental results of Ling [I64].

Refinements and generalizations

The proposed oversimplified model allows obviously refinements and variants. For instance, current circuits could run from exterior cellular space-time sheet to cell membrane space-time sheet and run only through the cell interior. In this case only the ionic concentrations in the cell interior would be controlled: this does not look a good idea. This option might be necessary in the case that cell exterior cannot be regarded as an electret carrying weak but stable electric field.

Several super-conducting space-time sheets are probably involved with the control and complex super-conducting circuits are certainly involved. The structure of the cell interior suggests a highly organized ohmic circuitry. In particular, cytoskeleton could be important carrier of currents and atomic space-times sheets of the microtubules could be in crucial role as carriers of the ohmic currents: there is indeed electric field along microtubule. The collagenous liquid crystalline networks [I76, I67] are excellent candidates for the carriers of weak ohmic currents in the inter-cellular tissue. Fractality suggests that also structures like proteins, DNA and microtubules are in a similar flow equilibrium controlled by super-conducting ion densities at protein/DNA/microtubule space-time sheets and probably also larger space-time sheets.

Bioelectromagnetic research provides a lot of empirical evidence for the existence of the direct current ohmic circuits, mention only the pioneering work of Becker and the work of Nordenström [J15, J17]. For instance, these direct currents are proposed to be crucial for the understanding of the effects of the acupuncture. The ancient acupuncture, which even now is not taken seriously by many skeptics, could indeed affect directly the densities and supercurrents of ions at super-conducting space-time sheets and, rather ironically, be an example of genuine quantum medicine.

Explanation of the paradoxes in terms of many-sheeted space-time

The qualitative predictions of the flow equilibrium model conform with the experimental facts discussed above.

1. One can understand how a gelatinous lump of matter can be a stable structure if the interior of the cell is in a gelatinous state in length scales larger than the size of the Josephson junctions at atomic space-time sheet. This means that water inside cell consists of coherent lumps larger than the size of Josephson junction and cannot leak to the exterior. If the exterior of the cell forms single large space-time sheet or consists of sheets connected by Josephson junctions with size larger than the typical size for the coherent lumps of water in cell exterior, cell exterior behaves like ordinary mixture of water and chemicals.

2. The amplification mechanism of supercurrents relying crucially on liquid crystal property implies that although liquid crystal pumps and metabolism are needed, the amount of metabolic energy can be extremely small. Absolutely essential is however that ohmic currents run through the super-conducting short circuit provided by the cell membrane space-time sheet.

3. The currents for various ions do not depend at all on the properties of the cell membrane but are determined by what happens on cellular and other superconducting space-time sheets. In flow equilibrium supercurrents and Josephson currents are identical with currents through cell membrane at atomic space-time sheet. The observed quantal nature of the ionic currents supports their interpretation as faithful atomic level images of supercurrents.

4. Since various ionic currents at the cellular space-time sheets dictate the ionic currents at the atomic space-time sheets, the selectivity of the cell membrane would seem to be only an apparent phenomenon. One must however be very cautious here. The self-organizing cell membrane might have the virtue of being co-operative and develop gradually structures

which make it easier to establish the flow equilibrium. For large deviations from the flow equilibrium, ohmic currents are expected to flow through the atomic space-time sheet associated with the cell membrane since super-conducting currents become overcritical and super-conductivity is spoiled. Also the proteinic Josephson junctions between lipid layer space-time sheets might be crucial. Thus the notions of channel and pump proteins might make sense in the far from flow equilibrium regime where the currents though membrane region are dominantly ohmic.

To sum up, one could see super-conducting space-time sheets as controllers of the evolution of the cellular and other biological structures and the model of organism could be specified to some degree in terms of the densities and currents of the super-conducting particles at various space-time sheets besides the values quantized magnetic fluxes associated with various many-sheeted loops. Setting up the goal at controlling space-time sheets would force the atomic space-time sheets to self-organize so that the goal is achieved. This clearly provides a quantum mechanism of of volition. A fascinating challenge is to apply this vision systematically to understand morphogenesis and homeostasis.

Needless to say, the notion of many-sheeted current circuitry would have also revolutionary technological implications since all undesired dissipative effects could be minimized and currents at atomic space-time sheets would be used only for heating purposes! Of course, many-sheeted current circuitries would also make possible quantum computer technologies.

Bio-control as a control of quantum numbers characterizing supercurrents

The magnetic quantum numbers K_i which together with the densities of super-conducting ions characterize the densities of various ions at atomic space-time sheets. Thus magnetic quantum numbers associated with super-conducting circuits formed by magnetic flux tubes indeed characterize biological information as speculated already more than decade ago on basis of mathematical necessity. Direct ohmic currents and supercurrents determine these quantum numbers only partially since in super-conducting circuit integer valued magnetic flux can flow without any induced current in the circuit. In presence of dissipation the currents in super-conducting circuit are minimal needed to guarantee quantized flux through the circuit.

In this picture biocontrol boils down to the changing of the various integers characterizing the phase increments over closed superconducting loops. If nerve pulse involves induction of supra curent compensating the deviation of the magnetic flux in circuit from integer multiple of flux quantum, this can be achieved. The coupling of super-conducting circuits with MEs makes it possible for MEs to affect the magnetic quantum numbers by time varying or constant magnetic fields.

1. If dissipation is slow, supercurrents and thus also ionic concentrations can suffer a large change and the homeostatis of neuron changes for a period determined by the rate of dissipation for supercurrents.

2. The induced a supercurrent could also dissipate rapidly to minimal supercurrent required by the quantization of the magnetic flux: the quantized part of the magnetic flux of external perturbation penetrates to super-conductor and is expected to affect the super-conducting part of the system. This does not of course occur permanently for oscillating em fields. The deviation of the external magnetic flux from a quantized value is coded to a small supercurrent. This mechanism combined with stochastic resonance possible for SQUID type circuits [D22] makes it possible to "measure" extremely weak magnetic fields of MEs by amplifying them to biological effects.

   MEs can also form junctions (possibly Josephson-) between two super-conducting circuits. In this case a constant electric field associated by ME defines the frequency of the induced Josephson current: the weaker the potential difference, the slower the oscillation period. This mechanism might explain why the effects of ELF em fields in living matter occur in intensity windows.

The role of the cell membrane

What is the role of the cell membrane in TGD inspired picture about cell? Very much what it is found to be. Cell membrane recognizes various organic molecules, interacts with them, and possibly allows them to go through. A protein in the cell membrane might act as an effective channel or pump but this function would be only apparent in case of ions. Only if cell membrane space-time sheet has join along boundaries bonds/magnetic flux tubes contacts with the cell interior, can ions and proteins enter cell interior through the membrane space-time sheet. One must also consider very seriously the possibility that cell membrane space-time sheet is a carrier of supercurrents participating in the control of the physics at atomic space-time sheets.

This vision conforms with a computer-ageist view about cell membrane as an interface between computer and clients. Against the fact that tools (proteins) and symbols (DNA) emerge already at atomic length scale, it would indeed seem rather strange that cell would reduce to a bag of water containing mixture of chemicals. This view conforms also with fractality. Skin is the largest connected part of the nervous system and cell membrane could be also seen as the skin of neuron and thus a part of the nervous system of cell, specialized to receive signals from the external world.

In this vision cell is much more like a living, intelligent computer than a sack of ion-rich water, and cell membrane is its interface with the external world. Proteins and biomolecules are messages/messengers, and cell membrane allows them to attach to the receptor only if a number of conditions are satisfied.

In many cases it is not necessary for the messenger to continue its travel to the interior since electromagnetic and electromechanical communications with the cell nucleus are possible by liquid crystal property of cell structures. TGD suggests MEs ("massless extremals") and magnetic flux tubes carrying ionic super-conductors as a universal tool for these communications, and the simplest hypothesis is that the fractally scaled down versions of the communications in the cell length scale are realized also in the interior of the cell and inside cell nucleus, and even at the level of DNA. The interaction of MES and topologically quantized magnetic fields could solve many of the paradoxical features related with the phenomenon of pleiotropy discussed briefly in [K70]. In particular, electromagnetic passwords and commands analogous to computer language commands based on suitable frequency combinations or even amplitude modulated field patterns could be involved. For instance, in case of DNA SQUID type mechanism combined with stochastic resonance could make possible the activation of specified genes by using specific frequency combinations associated with MEs.

6.2.4 Water Memory, Homeopathy, And Acupuncture

Further guidelines for TGD based view about biocontrol and coordination were provided by the empirical evidence for water memory and various effects involved with it [I42] [I43]. In [K44] a detailed mechanism of homeopathy and water memory based on the model of biocontrol in terms of many-sheeted ionic flow equilibrium is discussed.

1. Transfer of homeopathic potency to non-atomic space-time sheets is not enough

Many-sheeted ionic flow equilibrium suggests a possible mechanism of homeopathy: the extremely low densities of homeopathic remedies are at the controlling super-conducting space-time sheets where the control is. Thus homeopathy could be seen as a high precision medicine minimizing the amount of the remedy needed rather than some kind of magic treatment. This cannot be however the whole story. As already explained the study of homeopathic effects suggest an electromagnetic representation of the biomolecules based on frequencies [I31] and it is possible achieve the healing effect by transferring mere frequencies instead of using homeopathic potency.

2. Mechanisms of frequency imprinting and entrainment

According to [I31], the homeopathic remedies seem to be characterized by frequencies varying in the range containing at least the range $10^{-3} - 10^{9}$ Hz suggesting that electromagnetic fields at specific frequencies characterize the homeopathic remedy. These frequencies can be imprinted into water and also erased. Rather remarkably, the removal of Earth's magnetic field erases the imprinted frequencies.

One the other hand, the studies of acupuncture support the existence of certain highly coherent endogenous frequencies [I31] at which em radiation has strong effects. The fact that these frequencies can entrain to exogenous frequencies suggests a mechanism of homeopathy based on entrainment. Effects are observed at pairs of high and low frequencies and the ratio of these frequencies is constant over all acupuncture meridians with a standard derivation of $\pm.15$ per cent. The first branch is at GHz range: in particular the frequencies 2.664 GHz, 1.42 GHz and 384 MHz have unexpected properties. The second branch of frequencies is in ELF range, in particular Schumann frequency 7.8 Hz accompanies 384 MHz.

Consider now the explanation of the observations of Smith and others in in TGD framework using the proposed model assigning to magnetic flux tubes parallel MEs making magnetic flux tube effectively a magnetic mirror.

1. The basic idea is that water forms representations for chemicals it contains in terms of transition frequencies of the chemical which become frequencies of MEs and structures of water generating these MEs by emission and absorption processes. Also representations of representations are possible. The molecule of a homeopathic potency is characterized by characteristic frequencies associated with its transitions as well as ELF frequencies. Of course, also transitions of a complex formed by molecule of the potency and water molecule could be involved.

   Water represents the transition frequencies of the potency molecule as transition frequencies of water molecules or of structures which correspond to space-time sheets of various sizes. This conforms with the fact that frequency imprinting disappears after thorough drying and returns when water is added and that also bulk water without any potency allows frequency imprinting. In the frequency range studied by Smith rotational transition frequencies of water and of the space-time sheets containing water in liquid crystal form provide a good candidate for a representational mechanism. ELF frequencies correspond now to the magnetic transitions of these space-time sheets behaving like point like objects in Earth's magnetic field.

2. The simplest assumption is that the ELF branch of the frequency spectrum corresponds to the magnetic transition frequencies in Earth's magnetic field whereas the high frequency branch corresponds to the characteristic frequencies $f = c/L$ of MEs parallel to the magnetic flux tubes. This assumption conforms with the crucial role of Earth's magnetic field in the erasure of the imprinted frequencies. Also the importance of 7.8 Hz Schumann frequency for the heart chakra [I31] can be understood.

   The singly ionized Ca, Ar, and K (all 7.5 Hz for $B = .5 \times 10^{-4}$ Tesla) and Cl (8.5 Hz) have cyclotron transition frequencies near to Schumann frequency. For LC water blobs the ELF frequencies are below 1 Hz and the requirement that water blob has size smaller than radius of magnetic flux tube of Earth's magnetic field allows ELF frequencies down to $1/f \sim 1000$ years so that all biologically relevant length scales are covered. Quite interestingly, the frequency f_h corresponding 1000 years is 20 Hz by the scaling law suggested by Smith and corresponds to the lower bound for audible frequencies and that also language involves subneuronal mimicry by LC water blobs. A fascinating possibility is that subneuronal LC water blobs could be responsible for all biorhythms and be involved also with our long term memories.

3. Frequency entrainment for both ELF and high frequency branches can be understood if both the thickness and length of the magnetic flux tubes are subject to a homeostatic control. The assumption that the total magnetic energy of the flux tube remains constant during the frequency entrainment together with the magnetic flux quantization implies that the ratio S/L of the area S of the magnetic flux tube to its length L remains constant during entrainment. Thus the ratios f_h/f_{ELF} of the magnetic transition frequencies to characteristic frequencies of MEs would be homeostatic invariants in agreement with the empirical findings. The value of the ratio is in good approximation $f_h/f_{ELF} = 2 \times 10^{11}$.

4. The electromagnetic signature of the homeopathic potency corresponds to MEs stimulated by the electromagnetic transitions associated with the potency molecule. Since these frequencies are also transition frequencies for water molecules or space-time sheets contain water in liquid crystal form a resonant interaction is possible and em fields of MEs can be amplified/replicated by the transitions associated with these structures.

5. According to [I31], coherence propagates with a light velocity whereas coherent domain of size L diffuses with a velocity given by the scaling law $v \propto Lf$. In TGD the natural interpretation for the velocity of coherence propagation is as a signal velocity inside ME (possibly representing external em field). v is in turn associated with the motion of ME transversal to some linear structure along it: this effect is not possible in Maxwell's theory since particle-field duality is not realized at the classical level. The velocities are reported to be of order few meters per second and of the same order of magnitude as nerve pulse conduction velocity and phase velocities for EEG waves. This relationship is of the same form as the scaling law which relates together the phase velocity of EEG wave (velocity of EEG ME in TGD framework) and the size L of corresponding structure of brain or body. For instance, scaling law relates the size L for brain structures and corresponding magnetic sensory canvas with much larger size $L_c = c/f$ [K85]. Scaling law would give $v/c = f_{ELF}/f_h$ and velocity of order mm/s for the motion of transversal MEs along magnetic flux tubes: this velocity is considerably smaller velocity than m/s reported in [I31].

A detailed model for various homeopathic effects is discussed in [K44]. The model leads to a generalization of the view about many-sheeted DNA with magnetic mirrors transversal to DNA coding the electromagnetic structure of the organism and allows to understand introns as chemically passive but electromagnetically active genes. Magnetic mirrors provide also a recognition mechanism fundamental for the functioning of the bio-system: consider only the ability of amino-acids to find corresponding RNA triplets, the self assembly of tobacco mosaic virus and the functioning of the immune system. Magnetic mirrors can also serve as bridges between sender and receiver of intent in remote healing and viewing and these processes could be seen as scaled-up version of those occurring routinely endogenously.

6.3 The Roles Of Josephson Radiation, Cyclotron Radiation, And Of Magnetic Body

Before representing any detailed model for hearing, it is good to summarize the vision about the roles of Josephson radiation, cyclotron radiation, and of magnetic body on basis of the proposed general view about qualia and sensory receptors. The representation below is somewhat out of date and the updated and considerably more detailed view can be found in [L11].

6.3.1 The Role Of Josephson Currents

The general vision is that Josephson currents of various ions generate Josephson photons having dual interpretations as bio-photons and EEG photons. Josephson photons can in principle regenerate the quale in the neurons of the sensory pathway. In the case of motor pathways the function would be different and the transfer of metabolic energy by quantum credit card mechanism using phase conjugate photons is suggested by the observation that basic metabolic quanta 2 eV *resp.* 4 eV are associated with smooth muscle cells *resp.* skeletal muscle cells.

As already found in the previous section, the energies of Josephson photons associated with the biologically important ions are in general in visible or UV range except when resting potential has the value of -40 mV which it has for photoreceptors. In this case also IR photons are present. Also the turning point value of membrane potential is +40 mV so that one expects the emission of IR photons.

Josephson photons could be used to communicate the qualia to the magnetic body.

1. If Josephson currents are present during the entire action potential, the entire range of Josephson photons down to frequencies of order 2 kHz range is emitted for the standard value of $\hbar$. The reason is that lower frequencies corresponds to cycles longer than the duration of the action potential. The continuum of Josephson frequencies during nerve pulse makes it possible to induce cyclotron transitions at the magnetic body of neuron or large structure. This would make possible to communicate information about spatial and temporal behavior of the nerve pulse pattern to the magnetic body and build by quantum entanglement a sensory map.

fermion	$f_c(e)/MHz$	$f_c(u)/MHz$	$f_c(d)/MHz$
standard	.564	.094	.019
nearly vacuum extremal	8.996	2.275	.947

Table 6.1: Cyclotron frequencies of quarks and electron in magnetic field $B_{end} = .2$ Gauss for standard vacuum with very small Z^0 field and nearly vacuum extremal.

2. The frequencies below 2 kHz could be communicated as nerve pulse patterns. When the pulse rate is above $f = 28.57$ Hz the sequence of pulses is experienced as a continuous sound with pitch f. f defines the minimum frequency for which nerve pulses could represent the pitch and there remains a 9 Hz long range to be covered by some other communication method.

3. The cyclotron frequencies of quarks and possibly also of electron would make possible a selective reception of the frequencies emitted during nerve pulse. Same applies also to the Josephson frequencies of hair cell (, which does not fire). If the value of Planck constant is large this makes possible to communicate the entire range of audible frequencies to the magnetic body. Frequency would be coded by the magnetic field strength of the flux tube. Two options are available corresponding to the standard ground state for which Z^0 field is very weak and to almost vacuum extremals. For the first option one as ordinary cyclotron frequencies. The cyclotron frequency scales for them differ by a factor

$$r(q) = \frac{Q_{eff}(q)}{Q_{em}(q)} = \frac{\epsilon(q)}{2pQ_{em}(q)} + 1 \ per, \ \ \epsilon(u) = -1 \ \ , \epsilon(d) = 1$$

   from the standard one. For $p = .0295$ one obtains $(r(u), r(d), r(e) = (24.42, 49.85, 15.95)$. The cyclotron frequencies for quarks and electron with masses m(u)=2 MeV, m(d)=5 MeV, and m(e)=.5 MeV are given by **Table 6.1** for the two options. If one assumes that B_{end} defines the upper bound for field strength then he standard option would require both d quark and electron. Gor $d$quark with kHz CD the upper bound for cyclotron frequencies would be 20 kHz which corresponds to the upper limit of audible frequencies.

4. Besides cyclotron frequencies also the harmonics of the fundamental frequencies assignable to quark and electron CDs could be used and in case of musical sounds this looks a highly attractive option. In this case it is now however possible to select single harmonics as in the case of cyclotron transitions so that only the rate of nerve pulses can communicate single frequency. Lorentz transform sub-CD scales up the frequency scale from the secondary p-adic time scale coming as octave of 10 Hz frequency. Also the scaling of $\hbar$ scales this frequency scale.

6.3.2 What Is The Role Of The Magnetic Body?

The basic vision is that magnetic body receives sensory data from the biological body- basically from cell membranes and possibly via genome - and controls biological body via genome. This leaves a huge amount of details open and the almost impossible challenge of theoretician is to guess the correct realization practically without any experimental input. The following considerations try to clarify what is involved.

Is magnetic body really needed?

Libet's findings and the model of memory based on time mirror hypothesis suggests that magnetic body is indeed needed. What is the real function of magnetic body? Is it just a sensory canvas? The previous considerations suggest that it is also the seat of geometric qualia, in particular the pitch of sound should be coded by it. It would be relatively easy to understand magnetic body as a relatively passive sensory perceiver defining sensory map. If one assumes that motor action is like time reversed sensory perception then sensory and motor pathways would be just sensory pathways proceeding in opposite time directions from receptors to the various layers of the magnetic body. Brain would perform the information processing.

Certainly there must exist a region in which the motor and sensory parts of the magnetic body interact. What comes in mind is that these space-time sheets (or actually pairs of space-time sheets) are parallel and generate wormhole contacts between them. This interaction would be assignable to the region of the magnetic body could receive positive energy signals from associative sensory areas and send negative energy signals to motor motor neurons at the ends of motor pathways wherefrom they would propagate to premotor cortex, supplementary motor cortex and to frontal lobes where the abstract plans about motor actions are generated.

Is motor action time reversal of sensory perception in zero energy ontology?

One could argue that the free will aspect of motor actions does not conform with the interpretation as sensory perception in reversed direction of time. On the other hand, also percepts are selected -say in binocular rivalry [J37]. Only single alternative percept need to be realized in a given branch of the multiverse. This makes possible metabolic economy: for instance, the synchronous firing at kHz frequency serving as a correlate for the conscious percept requires a lot of energy since dark photons at kHz frequency have energies above thermal threshold. Similar selection of percepts could occur also at the level of sensory receptors but quantum statistical determinism would guarantee reliable perception. The passivity of sensory perception and activity of motor activity would reflect the breaking of the arrow of time if this interpretation is correct.

What magnetic body looks like?

What magnetic body looks like has been a question that I have intentionally avoided as a question making sense only when more general questions have been answered. This question seems however unavoidable now. Some of the related questions are following. The magnetic flux lines along various parts of magnetic body must close: how does this happen? Magnetic body must have parts of size at least that defined by EEG wavelengths: how do these parts form closed structures? How the magnetic bodies assignable to biomolecules relate to the Earth sized parts of the magnetic body? How the personal magnetic body relates to the magnetic body of Earth?

1. The vision about genome as the brain of cell would suggest that active and passive DNA strands are analogous to motor and sensor areas of brain. This would suggests that sensory data should be communicated from the cell membrane along the passive DNA strand. The simplest hypotesis is that there is a pair of flux sheet going through the DNA strands. The flux sheet through the passive strand would be specialized to communicate sensory information to the magnetic body and the flux sheet through the active strand would generate motor action as DNA expression with transcription of RNA defining only one particular aspect of gene expression. Topological quantum computation assignable to introns and also electromagnetic gene expression would be possible.

2. The model for sensory receptor in terms of Josephson radiation suggests however that flux tubes assignable to axonal membranes carry Josephson radiation. Maybe the flux tube structures assigned to DNA define the magnetic analog of motor areas and flux tubes assigned with the axons that of sensory areas.

3. A complex structure of flux tubes and sheets is suggestive at the cellular level. The flux tubes assignable to the axons would be parallel to the sensory and motor pathways. Also microtubules would be accompanied by magnetic flux tubes. DNA as topological quantum computer model assumes and the proposed model of sensory perception and cell membrane level suggests transversal flux tubes between lipids and nucleotides. The general vision about DNA as brain of cell suggest flux sheets through DNA strands.

   During sensory perception of cell and nerve pulse the wormhole flux tube connecting the passive DNA strand of the first cell to the inner lipid layer would recombine with the flux tube connecting outer lipid layer to some other cell to form single flux tube connecting two cells. In the case of sensory organs these other cells would be naturally other sensory receptors. This would give rise to a dynamical network of flux tubes and sheets and axonal sequences of genomes would be like lines of text at the page of book. This structure could have a fractal generalization and would give rise to an integration of genome to super-genome at the level of organelles, organs and organism and even hypergenome at the level of population. This would make possible a coherent gene expression.

4. This vision gives some idea about magnetic body in the scale of cell but does not say much about it in longer scales. The CDs of electrons and quarks could provide insights about the size scale for the most relevant parts of the magnetic body. Certainly the flux tubes should close even when they have the length scale defined by the size of Earth.

Additional ideas about the structure follow follow if one assumes that magnetic body acts a sensory canvas and that motor action can be regarded as time reversed sensory perception.

1. If the external world is represented at part of the magnetic body which is stationary, the rotation of head or body would not affect the sensory representation. This part of the magnetic body would be obviously analogous to the outer magnetosphere, which does not rotate with Earth.

2. The part of the magnetic body at which the sensory data about body (posture, head orientations and position, positions of body parts) is represented, should be fixed to body and change its orientation with it so that bodily motions would be represented as motions of the magnetic , which would be therefore analogous to the inner magnetosphere of rotating Earth.

3. The outer part of the personal magnetic body is fixed to the inner magnetosphere, which defines the reference frame. The outer part might be even identifiable as the inner magnetosphere receiving sensory input from the biosphere. This magnetic super-organism would have various life forms as its sensory receptors and muscle neurons. This would give quantitative ideas about cyclotron frequencies involved. The wavelengths assignable to the frequencies above 10 Hz would correspond to the size scale of the inner magnetosphere and those below to the outer magnetosphere. During sleep only the EEG communications with outer magnetic body would remain intact.

4. Flux quantization for large value of $\hbar$ poses an additional constraint on the model.

   (a) If Josephson photons are transformed to a bunch of ordinary small $\hbar$ photons magnetic flux tubes can correspond to the ordinary value of Planck constant. If one assumes the quantization of the magnetic flux in the form

   $$\int BdA = n\hbar$$

   used in super-conductivity, the radius of the flux tube must increase as $\sqrt{\hbar}$ and if the Josephson frequency is reduced to the sound frequency, the value of $\hbar$ codes for the sound frequency. This leads to problems since the transversal thickness of flux tubes becomes too large. This does not however mean that the condition might not make sense: for instance, in the case of flux sheets going through DNA strands the condition might apply.

   (b) The quantization of magnetic flux could be replaced by a more general condition

   $$\oint (p - ZeA)dl = n\hbar \ , \tag{6.3.1}$$

   where p represents momentum of particle of super-conducting phase at the boundary of flux tube. In this case also $n = 0$ is possible and poses no conditions on the thickness of the flux tube as a function of $\hbar$. This option looks reasonable since the charged particles at the boundary of flux tube would act as sources of the magnetic field.

(c) Together with the Maxwell's equation giving $B = ZeNv$ in the case that there is only one kind of charge carrier this gives the expression

$$N = \frac{2m}{RZ^2e^2} \quad (6.3.2)$$

for the surface density N of charge carrier with charge Z. R denotes the radius of the flux tube. If several charge carriers are present one has $B = \sum_k N_k Z_k e v_k$, and the condition generalizes to

$$N_i = \frac{2m_i v_i}{RZ_i \sum_k Z_k v_k e^2} \ . \quad (6.3.3)$$

It seems that this condition is the most realistic one for the large $\hbar$ flux sheets at which Josephson radiation induces cyclotron transitions.

What are the roles of Josephson and cyclotron photons?

The dual interpretation of Josephson radiation in terms of bio-photons and EEG photons seems to be very natural and also the role of Josephson radiation seems now relatively clear. The role of cyclotron radiation and its interaction with Josephson radiation are not so well understood.

1. At least cell membrane defines a Josephson junction (actually a collection of them idealizable as single junctions). DNA double strand could define a series of Josephson junctions possibly assignable with hydrogen bonds. This however requires that the strands carry some non-standard charge densities and currents- I do not know whether this possibility is excluded experimentally. Quarks and antiquarks assignable to the nucleotide and its conjugate have opposite charges at the two sheets of the wormhole flux tube connective nucleotide to a lipid. Hence one could consider the possibility that a connection generated between them by reconnection mechanism could create Josephson junction.

2. The model for the photoreceptors leads to the identification of bio-photons as Josephson radiation and suggests that Josephson radiation propagates along flux tubes assignable to the cell membranes along sensory pathways up to sensory cortex and from there to motor cortex and back to the muscles and regenerates induced neuronal sensory experiences.

3. Josephson radiation could be used quite generally to communicate sensory data to/along the magnetic body: this would occur in the case of cell membrane magnetic body at least. The different resting voltages for various kinds of cells would select specific Josephson frequencies as communication channels.

4. If motor action indeed involves negative energy signals backwards in geometric time as Libet's findings suggest, then motor action would be very much like sensory perception in time reversed direction. The membrane resting potentials are different for various types of neurons and cells so that one could speak about pathways characterized by Josephson frequencies determined by the membrane potential. Each ion would have its own Josephson frequency characterizing the sensory or motor pathway.

The basic questions concern the function of cyclotron radiation and whether Josephson radiation induces resonantly cyclotron radiation or vice versa.

1. Cyclotron radiation would be naturally associated with the flux sheets and flux tubes. The simplest hypothesis is that at least the magnetic field $B_{end} = .2$ Gauss can be assigned with the some magnetic flux quanta at least. The model for hearing suggests that B_{end} is in this case quantized so that cyclotron frequencies provide a magnetic representation for audible frequencies. Flux quantization does not pose any conditions on the magnetic field strength if the above discussed general flux quantization condition involving charged currents at the boundary of the flux quantum are assumed. If these currents are not present, $1/\hbar$ scaling of B_{end} for flux tubes follows.

2. The assumption that cyclotron radiation is associated with the motor control via genome is not consistent with the vision that motor action is time reversed sensory perception. It would also create the unpleasant question about information processing of the magnetic body performed between the receival of sensory data and motor action.

3. The notion of magnetic sensory canvas suggests a different picture. Josephson radiation induces resonant cyclotron transitions at the magnetic body and induces entanglement of the mental images in brain with the points of the magnetic body and in this manner creates sensory maps giving a third person perspective about the biological body. There would be two kind of sensory maps. Those assignable to the external world and those assignable to the body itself. The Josephson radiation would propagate along the flux tubes to the magnetic body.

4. There could be also flux tube connections to the outer magnetosphere of Earth. It would seem that the reconnections could be flux tubes traversing through inner magnetosphere to poles and from there to the outer magnetosphere. These could correspond to rather low cyclotron frequencies. Especially interesting structure in this respect is the magnetic flux sheet at the Equator.

6.3.3 Magnetic Homeostasis And Magnetic Circulation?

The possible importance of the precise value of the local magnetic field for say memetic code [K43] suggests that living matter has learned to control local magnetic field inside magnetic flux tubes just as it controls salt level of biological water.

Variation of the local strength of B_{end}

B_{end} -which is assigned to the magnetic body of particular body part- should scale as $1/\hbar$ to maintain the constant ratio of Josephson and cyclotron frequencies. This predicts hierarchy of cyclotron frequency scales coming in octaves if one accepts that the preferred levels of dark matter hierarchy come as $r = \hbar/\hbar_0 = 2^{k_d}$ with values of k_d fixed by Mersenne hypothesis introduced in introduction and discussed in detail in [K37]. Cell differentiation could lead to the differentiation of the local value of k_d and the value could vary even inside single cell nucleus.

Also a slight variation of the strength of B_{end} for a given value of r is possible. The condition that the ratios of Josephson frequencies and cyclotron frequencies remain constant means that the scalings of B_{end} and membrane resting potential are identical. Also the relative variation of EEG frequency scale would be same as that of the resting potential. The variation of resting potential is 10 per cent as is also that of EEG frequency scale so that this prediction is correct. Since the resting potential is characteristic of cell type [K37], also the value of B_{end} for corresponding part of magnetic body would be such. In the model of hearing the variation of both k_d decomposing the frequencies into octaves and smaller variations of B_{end} allowing to decompose octaves into smaller intervals would make possible to sense the pitch of the sound [K81]. This sense would be essentially a sensory quale assignable to magnetic body.

Magnetic circulation

There is a rather precise analogy with blood flow since both incompressible velocity field of blood and magnetic field are divergenceless: one can imagine magnetic flux to flow along "B-veins" (magnetic flux tubes) along organism or at least CNS. Variation of the magnetic field strength would be forced by the variation of the thickness of the flux tube since magnetic flux is conserved just as the variation of the thickness of blood veins affects blood flow. Artificial small alteration of local magnetic from outside would only interfere with this control.

For instance, alpha peak drifts in Hz range and this could be due the variation of the value of local magnetic field varies as much as 10 per cent. If this variation is due to the homeostatic variation of the local magnetic field, absolute variation should increase for higher frequencies: at the upper end of gamma band it would be 9 Hz. An alternative explanation for drifting is in terms of amplitude modulation: amplitude modulation of frequency f_1 by frequency f implies that original frequency is split to frequencies $f_1 \pm f$. In this case the amplitude of drifting does not depend on frequency.

The analogy with blood flow suggests that one could speak about B-circulation completely analogous to blood circulation: B-circulation could be crucial for bio-system to act as macroscopic quantum system. B-circulation would naturally accompany neural circuitry. It could be also accompany ordinary blood circulation physically or could form an independent system. The association with blood circulation would provide prerequisites for quantum control of also blood circulation and metabolism. The control could be based on MW frequency Josephson currents associated with ELF em fields inducing conformational changes of proteins coherently in large regions in turn giving rise to needed synchronous biochemical self-organization processes.

Temperature dependence of the local magnetic field strength

EEG frequencies are known to change with [I107] [J77] in the sense that the increase of the temperature raises the peak frequency of the power spectrum. This need not mean that the individual EEG frequencies are affected since the distribution of these frequencies could be affected due to the effects on the ionic conductances.

On the other hand, the equilibrium potentials for various ions are proportional to the temperature. In TGD framework this would predict that also EEG frequency scale is proportional to T so that the effect of temperature could be understood at least partially. Of course, very large drop of temperature known to induce sleep EEG involves dropping of higher EEG bands from the spectrum. The maximal reduction of body temperature have been to about 1 degree C and correspond to 10 per cent reduction of absolute temperature. 10 per cent variation is also characteristic variation of EEG band positions.

As far as nerve pulse generation is considered small reduction of temperature should lead to reduced membrane potential and if the value of the potential inducing nerve pulse does not follow, this would lead to a level of arousal. Maybe this could explain the stimulating effect of cold.

The question is whether cyclotron frequency scale follows the scale of the resting potential. If this is not the case, the communications to the magnetic body suffer from temperature changes since resonance conditions are lost. This could partially explain why a serious hibernation leads to a lower level of arousal. Cyclotron frequency scale can follow the change of the temperature as long as the transversal size scale of the magnetic flux quanta can react on the changes of the temperature and by flux conservation induce a change of the magnetic field strength. It is however highly questionable whether this is possible at distant parts of the magnetic body if it indeed can have the size scale of Earth.

The results of Blackman [J19] suggesting that ELF effects with given frequency disappear when body temperature is not in the range $36-37$ C inspires the hypothesis that quantum critical high T_c superconductivity and almost vacuum extremal property of the cell membrane space-time sheet are possible only in the range 36-37 C. This obviously provides a more plausible explanation for the effect of hibernation. In this picture the extreme importance of temperature regulation for the functioning of organism could be seen as a prerequisite for continual quantum control by magnetic transition frequencies.

Circadial temperature variation can be something like 20 Kelvins, which means relative variation about 10 per cent for poikilotherms, which is of same order as alpha frequency drifting. The relative width of the cyclotron resonance would be from this about 7 per cent ($\Delta f/f = \Delta B/B \propto \Delta T/T$). The relative variation of the membrane resting potential as a function of temperature is predicted to be sam.

Why the increase of the local magnetic field strength by factor of ten does not raise alpha band to heaven?

The increase of the local magnetic field strength by a factor $10-20$ is known to induce stress [J25] and confuse biological timekeeper mechanisms but it certainly cannot raise alpha band above 100 Hz as as a very naïve standard physics based application of the cyclotron frequency hypothesis would suggest.

In standard physics picture one could indeed argue that the increase of the strength of the local magnetic field interferes directly with bio-control and has catastrophic consequences. This is not the case of B_{end} corresponds to so large value of Planck constant that cyclotron energy corresponds to the energy of visible or UV photon and if the local magnetic field corresponds to the ordinary (or just different) value of Planck constant. That the variation local magnetic field has effect can be understood if the flux tubes of the dark magnetic field B_{end} are in contact with the those of the local magnetic field presumably having standard value of Planck constant. This would be classical interaction between visible and dark sectors of "world of classical worlds". One can of course imagine also other interaction mechanisms.

6.3.4 Some Remarks And Questions

Synchronizing effect of Earth's magnetic field

Earth's magnetic field could act as grand synchronizer of biorhythms of even separate organisms. Magnetic homeostasis does not prevent the effects due to the variation of Earth's magnetic field on human consciousness.

The close correlation of various cycles of biological and brain activity, in particular sleep-wake cycle, with periodic circadial variations of the geomagnetic field [J25], is consistent with this. Magnetic storms change temporarily the value of the local magnetic field and also this should have effects on consciousness. The statistics about mental hospitals supports this view [J25]. Also Persinger has proposed that the modulations of Earth's magnetic field caused by geomagnetic perturbations have effect on human consciousness [J25, J57]. Michael Persinger has studied extensively the effects of Schumann resonances on brain and has even explained religious and UFO experiences as correlates of this interaction [J57].

Also the diurnal changes of magnetic field caused by Moon having period of 25 hours are known and this variation seems to provide fundamental biological clock which sets on in absence of the normal 24 rhythm regulated by sunlight. The diurnal variations of the geomagnetic field are also responsible for sleep-awake rhythm: the increased melatonin secretion during dark hours correlate with the variation of Earth's magnetic field.

It is also known that the exposure to magnetic fields 10-20 times geomagnetic field induces stress in rabbits and slowed reaction time in humans; that the absence of geomagnetic field leads to a complete de-synchronization of biorhythms and that the synchronization of ELF biorhythms is coupled to ELF geomagnetic pulsations [J25]. In particular, pineal gland serves as biological timekeeper with cyclotron frequency of Co^{2+} ion defining the basic time unit of .1 seconds.

Dr. Phil Callahan [I5] claims on basis of intensive experimental work that there is a tendency of political strifes and wars to concentrate on regions where Schumann resonances are weak. This would not be surprising since Schumann resonances act as collective bio-rhythms if vertebrate brains are connected to the magnetic body of Earth.

3. What happens to astronaut's magnetic body

There is an old objection against the notion of magnetic body. If the local value of Earth's magnetic field is crucial for the brain functioning, astronauts should experience grave difficulties or at least dramatic changes in the character of consciousness. A possible estimate for the weakening of the local magnetic field is based on the scaling law $B \propto 1/r^3$ for dipole field. In this case a rough estimate for the relative change of the EEG frequency scale is $\Delta f/f = 3\Delta R/R \sim 6$ per cent for satellites moving below the ionosphere. This should affect the state of consciousness.

As a matter fact, there is reported evidence [J29, J76] that cosmonauts spending months in MIR had strange altered states of consciousness involving among other things precognition of the difficulties to be countered by MIR and receiving advices and identification experiences with other people and life forms, even dinosaurs of ancient Earth!

In the many-sheeted space-time the situation looks like following.

1. Only the levels k_d for which the size scale is between the size scale of personal magnetic body and the distance travelled could have been affected.

2. Astronauts could have drawn the magnetic flux sheets connecting them to the magnetic body of Earth and higher level magnetic bodies with them but long period could have led to a loss of the connections to the magnetic body of Earth.

3. At the level of cell nuclei nothing dramatic need happen. Energetically the stretching magnetic flux sheets associated with DNA is not a problem since the energy densities involved are rather tiny. Furthermore, if the flux sheets carry homological monopole flux, they could highly stable against increase of length since they would have magnetic monopole wormhole contacts at their ends.

4. A long period in space without contact with magnetic Mother Gaia might relate to the strange experiences reported by astronauts. One might imagine that the magnetic body of say solar system or even galactic magnetic body replaces Earth's magnetic body as a kind of fundamental reference frame. For instance, the third person perspective could rely on the inner magnetosphere which is at rest with respect to rotating Earth and the outer magnetosphere which does not rotate with Earth would provide even higher level reference system which begins to dominate in this kind of situation.

5. The experiences are consistent with TGD based view about geometric time and possibility of geometric memories extending beyond the duration of individual life cycle. There is also a consistency with Mersenne hypothesis summarized in the introduction and with the vision about long term memory inspired by this hypothesis [K37]. If one takes seriously the report about dinosaurs, which lived for $\sim 10^8$ years ago, the level $k_{eff} = 163 + k_d = 257$, which corresponds to Josephson period of about 10^8 years could have contributed to the conscious experience of astronauts. Therefore $k_d = 94$ characterizes the value of Planck constant as $r = \hbar/\hbar_0 = 2^{k_d}$. $k_{eff} = 257$ is consistent with Mersenne hypothesis. One has $257 = 239 + 18$, where $k_{eff} = 239$ is member of the twin pair $(239, 241)$ of Gaussian Mersennes suggested to be responsible for long term memory. $257-239 = 18$ in turn equals to the difference $107 - 89 = 18$ corresponds to the ratio of hadronic p-adic length scale $k = 107$ and intermediate boson length scale $k = 89$ defined by Mersenne primes. One cannot of course take the individual numbers deadly seriously: what is important the general view about memory based on hierarchy of weak physics assigned to Mersennes and their Gaussian counterparts suggests an explanation for the reported transpersonal memories.

5. What the reduction of Earth's magnetic field means?

The strength of Earth's magnetic field has reduced 50 per cent during last 1.000 years. The fact that an exponential evolution of civilization has occurred during this period, is perhaps not an accident. Surprisingly many magnetic transition frequencies happen to be near to Schumann resonance frequencies which do not depend on the strength of the magnetic field. If the scale of dark magnetic field B_{end} has followed the scale of B_E the the weakening of B_E furing this period has reduced cyclotron frequency spectrum of heavy ions from $3-8$ Hz range to the range $1.5-4$ Hz but leaving the spectrum of Schuman resonances unchanged. Rather remarkably, delta frequencies near 3 Hz correspond to a peak in the frequency spectrum of so called sferics associated with lightning activity [J41].

These observations suggest the emergence of strong interaction between brain and higher levels of the self hierarchy based on spherics and Schumann resonances. Assuming temporal linearity, the reduction of Earth's magnetic field has been 25 per cent after Newton and 5 per cent during last 100 years. Perhaps an exponential development of mathematical consciousness made possible by the activation of cyclotron frequencies of heavy ions with high nuclear and electronic angular momenta and allowing large number of conscious-to-us magnetic transitions, and possibly also involving some kind of fine tuning is taking place.

The weakening of Earth's magnetic field probably relates to a forthcoming change in the polarity of Earth's magnetic field. One might guess that the personal magnetic bodies are not affected appreciably during this period but that the violent change of Earth's magnetic field induces dramatic effects on collective aspects of consciousness at $k_d = 44$ level as the findings of Callahan suggest.

What about spin flips?

The natural question is whether also spin flips to which Larmor frequencies are associated could be important. If anomalous magnetic moment vanishes Larmor frequency differs by a factor 1/2

Ion	(Z, A, S)	f_1/Hz	f_{flip}/Hz	J
Cl	(17, 35, F)	8.5	82.2	3/2
K	(19, 39, F)	7.5	39.1	3/2
Rb	(37, 85, F)	3.5	81.0	5/2
Y	(39, 89, F)	3.4	41.2	1/2
Rh	(45, 103, F)	2.9	26.6	1/2
Ag	(47, 107, F)	2.8	34.2 (39.2)	1/2
Ir	(77, 193, F)	1.6	17.0	3/2
Au	(79, 197, F)	1.5	14.0	3/2

Table 6.2: The ions for which electronic spin vanishes in ground state and minimum spin flip frequency f_{flip} is below 90 Hz. f_{flip} is defined as $f_{min} = 2f_L/J$m, where J is nuclear spin. Ag allows two stable isotopes with almost same abundances and the values of f_{flip} are given for both.

from cyclotron frequency: $f_L = f_c/2$ so that spin flip frequency is same as cyclotron frequency. For atomic nuclei the Larmor frequency tends to be larger than cyclotron frequency as the table of Appendix demonstrates. The effects of em fields in living matter at Larmor frequencies have not been however reported.

The natural expectation is that Larmor frequency behaves in the same manner as cyclotron frequency in the scaling of Planck constant and this is indeed the case since spin scales as $\hbar_{eff}$. This allows to consider the possibility that also spin flip transitions are of interest and perhaps define correlates for sensory qualia.

Spin flip frequencies are in general of order few hundred Hz for $B = .2$ Gauss. The eight ions listed in **Table 6.2** have however exceptionally low Larmor frequencies and, very importantly, the singly ionized states have vanishing electronic spin for all ions except Rh and IR for which electronic configuration corresponds to $J - e = 2/2$ (non-vanishing electronic spin implies that the Larmor frequency of ion is of order $f_L = f_c(e)/2 \simeq 3 \times 10^5$ Hz). This suggests that electromagnetic spin flip transitions for these ions at least could be related to our consciousness. Note that K, Ag and Au have spin flip frequencies near to the harmonics of the fundamental frequencies of exotic super-symplectic representations important in EEG frequency range. Note that the spin flip frequency of K is 39.1 Hz which is in 40 Hz thalamocortical resonance band. The spin flip frequency 82.2 Hz for Cl might relate to the resonance frequency 80 Hz associated with retina.

6.4 Model For Ionic Superconductivity

In this section the model for ionic superconductivity is constructed as a straightforward generalization of the TGD based model of high T_c electronic superconductivity [K21]. There is however a exotic delicacy involved. TGD based model of atomic nucleus predicts that fermionic ions can have bosonic chemical equivalents for which one of the color bonds connecting nucleons to nuclear string is charged. Dark fermionic ions like Na^+, K^+, and Cl^- could appear as Cooper pairs or be exotic ions of this kind having different mass number and be able to form Bose-Einstein condensates.

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

6.4.1 Model For Ionic Superconductivity

TGD leads to a model of electronic super-conductivity based on the notion of magnetic flux tube pair. Exactly the same mechanism is expected to work also in the case of ions and the only differences come from the different mass and charge of ion.

1. The general idea is that magnetic flux tubes are carriers of dark charged particles including

ions and electrons. Usually magnetic field tends to destroy Cooper pairs since it tends to flip the spins of electrons of pair to same direction. In TGD flux quantization comes in rescue and magnetic fields favor the formation of Cooper pairs. If one has two parallel flux tubes with opposite directions of magnetic fluxes with large value of $h_{eff} = n \times h$, $S = 0$ Cooper pairs with even $L \geq 2$ are favored. This situation is encountered in systems near antiferromagnetic phase transition in small scales leading to formation of sequences of flux loops carrying Cooper pairs. Macroscopic super-conductivity results when the loops are reconnected to two long flux tubes with opposite fluxes. If the magnetic fluxes have same sign, $S = 1$ Cooper pairs with odd $L \geq 1$ are favored.

This model applies to both electrons and fermionic ions and if the proposal that h_{eff} is proportional to the mass of ion, it predicts same binding energies for all Cooper pairs as their spin-spin interaction energy. This hypothesis predicts universal spectrum of bio-photons energies if they result from dark photons and is motivated by the identification of gravitational Planck constant [K92] with h_{eff}. In this case binding energies would be in eV range and much above thermal energy at room temperature.

2. Mersenne hypothesis discussed in the introduction is assumed and makes possible precise quantitative predictions using scaling arguments. With the motivation coming from the model of cell membrane as Josephson junction it is also assumed that magnetic field scales as $1/\hbar$ and that the supra currents at the boundaries of flux tubes guarantee that the quantization condition $\oint (p - eA) \cdot dl = 0$ is satisfied. This allows the flux tubes to have a fixed transversal size (cell membrane thickness) irrespective of the value of Planck constant. The original hypothesis was that $B_{end} = 0.2$ Gauss and its p-adically scaled variants powers of two) could define preferred values of endogenous magnetic field. If biophotons result when dark photons with h_{eff} proportional ion mass are ordinary photons, they have a universal energy spectrum in visible and UV range, which directly corresponds to the spectrum of magnetic fields strengths and for flux tubes carrying monopole flux to the spectrum for the thickness of the flux tube. This would suggests effectively continuum of values of B_{end}.

3. In the case of bosonic ions there is no need for Cooper pairs and super-conductivity could be due to the Bose-Eintein condensation of ions. TGD based nuclear physics also predicts exotic ions, which are chemically like their fermionic counterparts but are actually bosons. This is made possible by the possibility of the color flux tubes connecting nucleons to nuclear string to carry charges $1, 0, -1$.

6.4.2 Super Conductors Of Exotic Bosonic Counterparts Of Fermionic Ions

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

TGD based nuclear physics [L3] allows this kind of ions. The model indeed predicts the possibility of exotic nuclei for which one or more color bonds connecting nucleons to the nuclear string are charged. These exotic nuclei with electronic states identical to those of genuine ions could save the situation. **Table 6.3** describes how cyclotron frequencies for $B = .2$ Gauss of the most important ions are modified in the simplest replacements with exotic ions. For instance, the notation Mg_-^{++} tells that there is double electronic ionization and electron shell of Argon as usual but that one color bond is negatively charged.

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

$$\begin{array}{llll} Ion & f_c/Hz & Pseudo-ion & f_c/Hz \\ {}^{23}Na^+ & 13.1 & {}^{19}Ne_+ & 15.7 \\ {}^{23}Na^+ & 13.1 & {}^{24}Mg_-^{++} & 12.5 \\ {}^{39}K^+ & 7.7 & {}^{40}A_+ & 7.5 \\ {}^{39}K^+ & 7.7 & {}^{40}Ca_-^{++} & 7.5 \\ {}^{35}Cl^- & 8.6 & {}^{40}A_- & 7.5 \end{array} \tag{6.4.1}$$

Table 6.3: The modification of cyclotron frequencies of most important ions are modified by simplest replacements with exotic ions

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

Table 6.4: The first columns give the cyclotron frequencies and cyclotron energies for biologically relevant bosonic ions in $B_{end} = .2 \times 10^{-4}$ Tesla. The third column gives cyclotron energy.

6.4.3 More Quantitative Picture About Bose-Einstein Condensates

Cyclotron frequencies of biologically important ions in the endogenous magnetic field $B_{end} = 0.2$ Gauss are involved with the effects of ELF em fields on vertebrate brain and are also central in the model of EEG [K37]. This motivates a more detailed study of these frequencies. Also the cyclotron frequencies of biologically important molecules are interesting.

Bose-Einstein condensates of bosonic ionized atoms

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

The table inspires some comments.

1. For Li^+ the dominating isotope ${}^7Li^+$ is fermion. ${}^6Li^+$ is boson and its abundance is 5 per cent. Li^+ ions are used as medications in mania and represents mood stabilizer [J3]. A possible explanation is that the cyclotron oscillations of Bose-Einstein condensate of ${}^6Li^+$ ions serve as a biological clock helping to stabilize the mood. The cyclotron frequency is however 50 Hz and higher than thalamocortical resonance frequency having nominal value 40 Hz.

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

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

2. For Mg^{2+} cyclotron energy corresponds to the energy of photon of green light. Chlorophyll is not able to convert nutrients to sugar without magnesium, which suggests that cyclotron

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

Table 6.5: The first columns give cyclotron frequencies and corresponding cyclotron energies for some ions in $B_{end} = .2 \times 10^{-4}$ Tesla for some fermionic ions.

transitions of Mg BE condensate are at least partially responsible for the green color of plants. Mg BE condensate could control the coherent occurrence of photosynthesis in the size scale of plant.

3. For oxygen ion the cyclotron frequency is 37.6 Hz and rather near to $\sim$ 40 Hz thalamocortical resonance frequency, which suggests that the cyclotron transitions of oxygen ions might play key role in inducing coherent firing of neurons at this frequency. This would mean that oxygen would be much more than a mere provider of metabolic energy. Note also that $\Delta n = 3$ cyclotron transition of Na^+ ion corresponds to frequency 39 Hz and might be involved with the synchronous firing.

4. Ca^{2+} ions play a unique role in the functioning of living matter. In particular, calcium waves appearing in a wide range of time scales are known to serve a crucial role in nervous system [J54]. Ca^{2+} corresponds to.99 eV cyclotron energy scale, which is twice the energy of metabolic energy quantum. Hence one can ask whether the cyclotron transitions of Ca^{2+} BE condensate could induce a collective emission of metabolic energy quanta and in this manner induce coherent metabolic activity in the scale of entire body.

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

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

Cyclotron frequencies and Schumann frequencies

Even in the case that Cooper pairs of fermionic ions are not thermally stable, the cyclotron transitions of fermionic ions like K^+, Cl^-, and Na^+ are expected to be important. In **Table 6.5** cyclotron frequencies and energies of some fermionic ions are given. Notice that the cyclotron energy of K^+ ion corresponds to metabolic energy quantum. Quite generally fermionic ions cannot be involved with the generation of Josephson part of EEG.

The first thing to notice is the close relationship of cyclotron frequencies with the lowest resonance frequencies in the spectrum of geo-electromagnetic field starting from 5 Hz, so called

Schumann frequencies [F7], are $7.8, 14, 20, 26, 33, 39$ and 45 Hz. 5 Hz corresponds roughly to the threshold 4 Hz of theta frequency range below which EEG spectrum lies during sleep which suggests that wake-up state involves the coupling of brain with geo-electro-magnetic activity. 7.8 Hz corresponds to the threshold for alpha waves associated with wake-up state without cognition; 14 Hz corresponds to threshold of 13 Hz for beta waves accompanying cognitive activities, and 33 Hz is quite near to the threshold 30 Hz for gamma waves known to be important in the temporal coding of sensory data.

Consider now examples of cyclotron frequencies keeping in mind that Schumann frequencies vary typically within 1 Hz interval around their mean values [F7].

1. As already noticed, the frequencies, which are multiples of 15 Hz can be assigned to Ca^{2+} ion. The excitations $n = 3, 5, 7, ..$ correspond to the frequencies $45, 75, 105, ...$ Hz. All these frequencies have been observed. The two lowest frequencies correspond to Schumann frequencies 14 and 45 Hz with accuracy of 1 Hz.

2. Na_+ has $A = 23$ and gives $f = 13$ Hz. This is the lower bound for the frequency of beta EEG waves which are associated with conscious cognition. This would suggest that the presence of em field of 13 Hz frequency correlates with large fluxes of Na_+ ions through the axonal cell membrane during nerve pulse generation. This could result from increased amplitude of Na_+ Josephson current facilitating the emission of nerve pulses at the second half of the EEG cycle. Silencing of mind by meditation or closing eyes reduces amplitudes associated with EEG frequencies below 13 Hz and conscious cognition disappears.

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

3. K_+ has $A = 39$ and gives $f = 7.5$ Hz, which is theta frequency rather near to the lowest Schumann resonance frequency 7.8 Hz. K_+ ion flux could correlate with em fields in the range of the alpha frequencies creating cyclotron resonance. Theta activity dominates during sleep and Adey's observations [J25] demonstrate that 7 Hz ELF field increases reaction times. Second and third transition frequencies are within 1.5 Hz Schumann frequencies 20 and 37.5 Hz.

4. Cl_- ion has $A = 35$ and gives $f = 8.5$ Hz. Chloride ion has inhibitory effect. $n = 3, 7, ..$ excitations correspond to 25.5, 42.5 Hz, ... Rather interestingly, frequencies rather near to 40 Hz associated with thalamo-cortical loops appear as excitations for all ions relevant to nerve pulse activity. Note that 39 Hz is also Schumann frequency. Two lowest transition frequencies of Cl_- are quite near to Schumann frequencies 7.8 and 25 Hz.

5. Fe^{2+} has $A = 56$ and corresponds to 10.7 Hz. $3f_c(Fe^{2+}) = 32.2$ Hz is rather near to Schumann frequency 33 Hz whereas Co^{2+} corresponds to 10 Hz in excellent accuracy. Co has especially large nuclear magnetic moment and serves as a natural magnet. Fe^{2+} and/or Co^{2+} could be present in magnetic sensory organ possessed also by humans making it possible to navigate using magnetic fields. Yarrow suggests that Co makes B_{12} magnetic vitamin [J25] so that it can serve as fundamental biological clock at frequency very precisely equal to 10 Hz. Co is carried by B_{12} vitamin and is known to be important for normal consciousness: among other things the lack of B_{12} causes fatigue, blurred vision and cognitive problems.

6. Mg^{2+} has A=24 and $f = 25$ Hz which is near to Schumann frequency: $n = 3$ corresponds 75 Hz. Charged polypeptides could also form BE condensates and be involved with cyclotron mechanism: they are rather heavy and their cyclotron frequencies are in Hz range. Negatively charged organic molecules are indeed known to be present in neurons.

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

What about proton's cyclotron frequency?

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

The duration of single bit of the memetic codeword consisting of 127 bits and having total duration defined by the p-adic timescale $T^{(2)}_{M_{127}} = .1$ seconds corresponds to the frequency $f_m = 1027$ Hz. This frequency is by 10 per cent higher than the cyclotron frequency of proton for $B_{end} = .2$ Gauss. If magnetic homeostasis is realized, as will be discussed later, and if it allows 10 per cent variation of the strength of magnetic field as the width 1 Hz of alpha band suggests, it is possible to realize this frequency as proton's cyclotron transition frequency.

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

Bose-Einstein condensates of bosonic molecular ions

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

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

6.5 Atmospheric Phenomena And Super-Conductivity

There is a lot of evidence that various electromagnetic time scales associated with the atmospheric phenomena correspond to those associated with brain functioning. If magnetic sensory canvas hypothesis holds true, this is just what is expected. In this section these phenomena are considered in more detail with the aim being to build as concrete as possible vision about the dynamics involving the dark matter Bose-Einstein condensates at super-conducting magnetic flux quanta. If almost vacuum extremals are in question, a strong analogy with living matter is implied and both em and Z^0 fields are present. In case of cell membrane this assumption is highly successful.

One particular consequence is that there is a coupling to left handed weak nuclear isospin proportional to neutron proton difference as well as coupling to nuclear electromagnetic charge Z which dominates for heavier nuclei and gives rather large coupling (here it is essential that atomic electrons do not condense at the almost vacuum extremal). This means that the system behaves like plasma such that all particles have same sign of net weak isospin. Either opposite Z^0 charge carried by neutrinos or ionization is necessary in order to achieve stability. Also large parity breaking is implied in macroscopic length scales. One implication would be vortices with a preferred direction of rotation.

6.5.1 Tornadoes As A Macroscopic Quantum Phenomenon Involving Super-Conductivity?

Tornadoes represent a piece of not completely understood atmospheric physics. To mention just two questions which have received no satisfactory answer.

1. What makes possible the ability of tornado to preserve its structure and coherence?

2. What makes possible the coherent rotation of matter inside tornado?

3. How to understand various luminous phenomena associated with the tornadoes [H10, H1, H29] ?

Classical Z^0 forces and the vision about magnetic flux tubes as bio-superconductors suggests a new approach to the physics of tornados possibly providing also answers to these questions. My own attempts to understand tornadoes have been based on three separate approaches. Tornado as a magnetic spiral vortex carrying em and Z^0 magnetic fields, tornado as an analog of a rotating magnetic system known as Searl device, and tornado as a system for which the interactions between visible and dark matter are essential.

The most recent approach to tornadoes and rotating magnetic systems relies on the recent model of cell membrane as almost vacuum extremal and assumption that tornades could be seen in many respects as p-adically scaled up variants of the axonal membrane. The combination of this line of approach with the earlier ones, probably not mutually consistent in every detail, will be discussed in the sequel.

Tornadoes as magnetic spiral vortices near vacuum extremals?

The basic idea is that tornadoes are a phenomenon involving complex many-sheeted space-time topology and classical em and Z^0 magnetic fields in an essential manner making tornadoes macroscopic quantum systems in meteorological length and time scales.

1. A partial answer to the question relating to the stability and coherence is self-organization, which in fact implies in TGD context that tornado has "self" and is conscious in some primitive sense. In standard physics context the ability of tornado to have a well defined macroscopic structure despite the locally chaotic nature of the hydrodynamic flow involved, is not easy to understand. In particular, self-organization does not as such explain the coherent rotation of the matter inside tornado. The almost vacuum extremal property is characteristic aspect of cell membrane [K37], which suggests that tornado or at least the boundary layer between exterior and interior of tornado corresponds to almost vacuum extremal so that tornado might be perhaps compared to neuronal axons in some respects. Self organization is indeed associated with strong gradients and the boundary layer certainly represents this kind of region.

2. In TGD framework the answer to the question relating to the rotation of matter inside tornado is that tornado or its boundary corresponds to magnetic flux tube with em and Z^0 magnetic fields -or more generally -a more complex structure consisting of magnetic flux quanta, say a hierarchy of hollow flux tubes inside hollow flux tubes.

3. One expects that these Z^0 ions rotate with almost the same rotation velocity and in the same direction in the Z^0 magnetic field associated with the space-time sheet of the tornado. Although rotation velocities can have both signs, coherent motion in single direction can occur stably and large parity breaking favors the other direction of rotation. Z^0 magnetic field is generated if all screening neutrinos do not co-rotate with the matter or if the screening of nuclear Z^0 charge by neutrinos is not complete. Conducting and super-conducting neutrinos are expected to be unable to follow the rotation of the nuclei whereas the neutrinos below Fermi surface should co-rotate with matter so that Z^0 magnetic field can be generated. Situation is completely analogous to that of an electric conductor.

4. Neutral atoms and molecules are highly charged Z^0 ions with effective charge proportional to nuclear charge if electrons do not condense on almost vacuum extremal. The quantization of em and Z^0 magnetic field of tornado to flux tubes suggests strongly itself and the classical orbits of Z^0 ions in the average Z^0 magnetic field correspond to Z^0 magnetic flux tubes with a helical shape. In the case of tornado these flux tubes are expected to have spiral like structure implied by garden hose instability and provide an example of spiral waves which seem to be a very general phenomenon in excitable media. Just like the flux tubes of the magnetic field, also Z^0 magnetic flux tubes are expected to be super-conducting. One of the first proposals of TGD inspired view about supra phase was that also super-fluidity might involve Z^0 magnetic vortices [K51] but at that time I did not realize that almost vacuum extremals- which I was of course well aware- might be in question.

5. Also the vortices of any hydrodynamic flow could involve Z^0 magnetic boundary layers at least: in particular, the mechanism inducing transition from superfluidity to ordinary fluid flow is generation of Z^0 magnetic vortices at critical velocities which are much lower than those predicted by hydrodynamical arguments [K51]. The leakage mechanism of radial em or Z^0 supra currents from magnetic flux tubes might be involved with the dissipation and also with sono-luminescence [C1]. Also TGD inspired cosmology and classical view about gravitational fields relies on the approximation that cosmologies can be idealized with vacuum extremals [K114].

To build a more quantitative picture one needs some information about the model for almost vacuum extremals.

1. In the model of cell membrane as almost vacuum extremal electrons are not assumed to condense at the almost vacuum extremal space-time sheets since this would not be consistent with atomic physics. Nuclei however feed their Z^0 charges to these space-time sheets. Neutral atoms for $N-Z>0$ have left-handed weak isospin equal to $(Z-N)/2$ and same vectorial charge proportional to $sin^2(\theta_W)Z$. The classical Z^0 field is for vacuum extremal proportional to em field and this allows to use only em field and effective em charge expressible as

$$Q_{eff} \quad = \quad -\frac{Z-N}{2p}+2Z+q_{em} \quad , \quad p=sin^2(\theta_W) \ . \tag{6.5.1}$$

   Z denotes proton number, N neutron number, and q_{em} the charge due to ionization in units of proton charge. What is remarkable that even neutral atoms have large effective em charge due to the charge of protons. There is also an axial coupling to the classsical Z^0 field causing large parity breaking effects. The value of Weinberg angle for almost vacuum extremals is not expected to be same as for far from vacuum extremals. The model for photoreceptors fixes p to be $p=.0295$ to be compared with $p\simeq .23$ for standard model vacuum. Just fixing the value p predicts correctly the frequencies of peak sensitivity for the four types of photoreceptors [K37].

Radiation at visible photon energies is the signature of tornadoes [H5] difficult to understand in the standard physics framework. Also rotating magnetic systems [H27] exhibit similar strange characteristics. Same applies to sonoluminescence [C1]. One can consider two mechanisms generating radiation at visible and UV frequencies.

1. First mechanism is based on Josephson radiation. The almost vacuum extremal property, the suggested membrane like structure at the boundary of tornado, and the hypothesis that scaled up variant of axonal membrane with an appropriate value of Planck constant could in question suggests that there is also an electric field over the membrane. T TGD based model for rotating objects also predicts radial electric field [K114] and there is also a kinematic effect producing this kind of electric field [K12]. From the vanishing of total Lorentz force one has $E=\omega\rho B$, where B is the strength of the magnetic field, ω the angular velocity of rotation, and ρ is the distance from the rotation axes. For $\omega k/\rho$ outside the rotating magnetic system voltage is same for all flux sheets and voltage is

$$V = k\Delta RB = \omega R\Delta RB \ .$$

If the value of the analog of membrane potential is same as for cell membrane, one would have electric strength ~ 9.5 V/m for the minimal sized vortex. This condition would relate the magnetic field strength to the basic parameters of the tornado. This kind of assumption is of course somewhat ad hoc and only its success can justify it.

Superconducting atoms and molecules would be Z^0 ions with effective em charge proportional to the total nuclear charge Z and gain in this electric fields energies comparable in visible and UV range (few eVs) and one expects that the dark Josephson radiation at low frequencies is generated providing the system with the analog of EEG. The leakage of dark Josephson photons and $Z0$ ions to the ordinary space-time sheets and their interaction with atoms and molecules could in turn induce ordinary ionization which might be required also by the stability of the system. This would explaoin the visible light from this kind of systems. The rotation frequency of the system might directly relate to the frequency of dark Josephson radiation. The energy spectrum of radiation would serve as a signature allowing to distinguish the model from models explaing the radiation in terms of atomic transitions.

2. One can consider also second mechanism. The mechanism for the breaking of the ordinary super-conductivity in the case of the magnetic flux tubes is based on the idea that for curved flux tubes ionic current with an overcritical ion velocity leaks along flux tubes from the magnetic flux tubes to non-super-conducting space-time sheets. The reason is simply the inertia of the charged particle. This process implies the generation radiation in case of the ordinary electromagnetic ions. This process occurs in the reconnection of magnetic flux tubes and more generally, when the curvature of flux tube becomes very large so that the inertia of the particle drives it to a larger space-time sheet. The model applies also to Z^0 magnetic case and if the particles are ordinary em ions, the generation of radiation is expected also now. Of course, also the collisions of neural particles generate also radiation but much more weakly. It is of course possible that stability condition requires also ordinary ionization of atoms.

   This mechanism, besides providing a model for dissipation, might explain also the luminous phenomena associated with tornadoes [H10, H1, H29]. Tornadoes are expected to involve also ordinary magnetic fields and corresponding flux tube structures so that also they could give rise to luminous phenomena by the same mechanism as in the case of auroras.

Rotating magnetic systems as dark matter systems analogous to neuronal axon

A useful analogy for the tornado is provided by rotating magnetic system known as Searl device [H27]. This system is reported to starts to spontaneously accelerate at certain critical rotation frequency. The TGD inspired model for the system is discussed in [K12]. Spontaneous acceleration is accompanied by spontaneously occurring concentric cylindrical magnetic walls of thickness $\simeq .5$ cm with mutual distance of $\simeq .5$ m. What is intriguing that the spontaneous acceleration starts at 9.1 Hz rotation frequencyandacceleration continues up to 10 Hz after which the experimentation brecomes impossible due to the problems with the mechanical stability. 10 Hz corresponds to the alpha band of EEG and to the fundamental frequency of electron's CD. There is also a strong parity breaking involved: depending on the direction of rotation the weight of the system either decreases or increases, which suggests that some space-time sheets involved correspond to almost vacuum extremals: this could also explain the problems with stability.

These observations suggest that it might make sense to apply the idea about scaled up cell membrane to the boundary layer and magnetic flux walls associated with the rotating magnetic system. There are several scales and possibly also several values of Planck constant involved.

1. The radius of the rotating magnetic system is about 1 m and corresponds to the p-adic length scale $k = 204$ which corresponds to 1.2 m. This would suggest $k_d = 204 - 163 = 41$. Note that one has $h_{eff} = nh$, where n is product of distinct Fermat primes and power 2^{k_d}. The distance between magnetic walls is about.5 m and would correspond to $k_d = 39$. The thickness of the magnetic walls is about 5 cm corresponding to about $k_d = 32$. It is difficult

to say anything definite about the thickness of the boundary layer assignable to the rotating magnetic system. 1 mm is one estimate based on the fact that the cylindrical rollers are at this distance from the central cylinder. This would suggest $k = 184$ and $k_d = 21$. The corresponding dark photon frequencies are 320 Hz, 1280 Hz, .66 MHz, and.32 GHz. Note that the second frequency corresponds to the 1.28 kHz frequency asignable to the CD of quark.

2. The very special role of 10 Hz frequency suggests the value $k_d = 2^{46}$. Note that the time scale of electron's CD is in question. Of course, several dark values of Planck constant are possible.

3. One can also consider the possibility that magnetic walls of thickness 5 cm could be dark matter systems with thickness allowing an interpretation as scaled up counterparts of cell membran of thickness 10 nm. The ratio of these scales is 5×10^6. This would give $k_d = 2^{45}$ not far from the value deduced from 10 Hz critical rotation frequency. Here one must however notice that cell membrane thickness is not affected in the scalings of Planck constant so that also other values of Planck constant are possible.

The idea about a strict scaling of the cell membrane suggests that there is also an electric field orthogonal to the boundary layer. From the vanishing of the total Lorentz force one has $E = \omega\rho B$, where B is the strength of the magnetic field, ω the angular velocity of rotation, and ρ is the distance from the rotation axes. For $\omega = k/\rho$ outside the rotating magnetic system voltage is same for all flux sheets and voltage is $V = k\Delta RB$.

If the value of the analog of membrane potential is same as for the cell membrane, one would have electric strength ~ 9.5 V/m. Superconducting atoms and molecules in in this field would gain energies of UV photons and highly energetic dark Josephson radiation at these frequencies would be generated providing the system with the analog of EEG. If the voltage is same also in the case of cell membrane, dark Josephson radiation at frequencies determined by the value of the Planck constant is generated. The rotation frequency of the system -very near to 10 Hz- might relate to the frequency of Josephson radiation.

Magnetic walls could contain dark matter Bose-Einstein condensates in cyclotron state carrying maximal magnetic field of $B = .05$ Tesla [K12], [H27]. Magnetic walls could serve as angular momentum and energy storages from which the system draws energy by time mirror mechanism (see **Fig.** `http://tgdtheory.fi/appfigures/cat.jpg` or **Fig. ??** in the appendix of this book), which means sending of negative energy phase conjugate photons absorbed by the Bose-Einstein condensate.

One can imagine several interpretation for the ionization of the air.

1. One already discussed explanation for the ionization of air would be in terms of energetic dark atoms and molecules and dark Josephson radiation leaking to the space-time sheets carrying visible mater. For instance, for N_2 and O_2 molecules one has Z_{tot} equal to 15 and 16 respectively, and the energies of UV photons are in few eV scale for cell membrane potential and could ionize molecules [K37].

2. The observed ionization of the air in the vicinity of the rotating system could be also understood in terms of an Ohmic current generated by the radial vacuum electric field implied by the rotating magnetic field. Since the electric field corresponds to a non-vanishing vacuum charge density, this current charges the rotating magnetic system. Current carriers drop from atomic space-time sheets to larger space-time sheets at the boundary of the system liberating their large zero point kinetic energy of order 1 keV. The resulting voltage allows in principle to use the system as an over-unity device by adding load to a wire connecting the system to ground. The model leads to the proposal that rotating magnetic flux quanta provide a fundamental mechanism leading to the generation of plasmoids, which can be regarded as primitive living systems [I74].

Tornadoes as dark matter systems

The identification of tornadoes as large $\hbar$ systems is suggested by the ability to self-organize and preserve the self-organization pattern for relatively long periods of time. Dark matter would imply self organization and make the system living in a primitive sense.

The identification of tornadoes as rotating magnetic systems near vacuum extremals would allow to interpret the luminous phenomena associated with tornadoes [H10, H1, H29] in terms of a plasma resulting by the mechanisms proposed in previous section. The angular momentum stored to dark Bose-Einstein condensates at the magnetic walls would provide angular momentum and energy for the tornado. As a matter fact, the formation of these Bose-Einstein condensates could force the rotation of tornado by angular momentum conservation.

The already discussed model of the boundary layer between rotating magnetic system and external world as a scaled up variant of cell membrane space-time sheet applied to the boundary layer between tornado and external world would make essentially the same predictions if one assumes that the voltage through the layer is same as in the case of the cell membrane. In particular, ionization is expected by the atoms and molecules gaining energies corresponding to photons in visible and UV regions and the resulting ions would in turn generate Josephson photons.

There are several kinds of tornadoes [H5]. For supercell tornadoes called twisters the width is usually below $d = 90$ m but can sometimes extend over 1.6 km. Wind velocity is typically $v_0 = 160$ km/h= 44 m/s at the outer boundary. This gives a rough estimate for the angular velocity at the outer boundary as $\omega = v/d$. The rotation frequency is $f = 1/2\pi \simeq .16 \simeq 2^{-6} \times 10$ Hz in this particular case. For a radius of 1.6 km and same wind velocity one would have $f \simeq 8.8$ mHz $\simeq 2^{-10} \times 10$ Hz By the basic rule the values of k_d vary in the range $[52, 56]$ with p-adic length scales $163 + k_d$ in the range $[215, 218]$. The length scale range would be [40, 113] m. What is encouraging that the lower limit corresponds to the radius of the minimum sized tornado. The upper limit is too small by an order of magnitude. The interpretation suggested by the interpretation in the case of rotating systems is that 114 m would correspond to the thickness of the boundary layer between tornado and exterior world. For the minimal tornado the boundary layer would cover the entire interior.

6.5.2 Auroras As An Astrophysical Quantum Phenomenon?

Auroras are perhaps the most magnificent electromagnetic phenomenon in the atmosphere. The mechanism generating the auroras is not completely understood. What is however known that auroras involve the motion of ions along flux lines of Earth's magnetic field acting effectively as current wires. This suggest the that the ionic currents could be supra currents running along the flux tubes of the magnetic field of Earth or its dark counterpart $B_{end} = 2B_E/5$ suggest to exist on basis of findings about the effects of ELF em fields on vertebrate brain [K37]. Hence auroras could be a directly visible macroscopic quantum phenomenon! In the following a model of auroras based on this vision and explaining the latest findings about them is developed.

Basic facts, ideas and puzzles related to auroras

Auroras occur at heights of 56-970 km along a circle surrounding the magnetic North (South) pole [F16]. Magnetic storms accompany auroras and auroras are especially intense during sunspot maxima. Protons and electrons of the solar wind are known to flow along magnetic flux lines acting effectively as current wires. Some mechanism accelerates electrons and protons during their travel to the pole region where they collide with the ions (mainly oxygen and nitrogen) of the ionosphere and generate visible light. The spectral lines correspond to ionic transitions and each color corresponds to a particular ion dominating at a particular height.

A brief summary of the basic ideas and problems related to the auroras is in order before representing TGD based model.

1. The reconnection of solar magnetic field lines carried by solar wind with the field lines of Earth's magnetic field was proposed by James Dungey as a mechanism explaining the energetics of the auroras. There is indeed increasing empirical support for the view that the reconnection of the magnetic field lines of Sun and Earth accompanies [F16] [F6, F11, F5]. What would happen would be that the reconnected nearby opposite fields lines form a tightly bent U-shaped structure which straightens and acts as a catapult giving recoil energy to the plasma ions flinging in the direction of Earth. The highly energetic protons and electrons of the solar wind would flow towards Earth and collide with the ions of atmosphere and generate the auroras in this manner. The detailed understanding of the reconnection mechanism is

lacking and here TGD suggests microscopic topological description relying on magnetic flux tubes.

2. The problem of the reconnection mechanism is how the solar and earthly magnetic flux lines running in opposite directions and carrying opposite currents know of each other and can change their direction so that the lines can meet. In TGD framework the reconnection of the magnetic flux tubes could be seen as a process changing space-time topology and this process is now one of the basic mechanisms of TGD inspired quantum biology [?]. At the point of reconnection magnetic field becomes zero in Maxwell's theory and it is thought that the charged particles must be able to leave the flux lines by some unknown mechanism so that demagnetization occurs. TGD in turn suggests that inertial effects force ions flow to larger space-time sheets along join along boundaries bonds.

3. An electric field parallel to the magnetic flux lines has been postulated as the mechanism of acceleration: empirical evidence for the existence of this electric field has been found quite recently [F10]. Two U shaped potential regions with positive *resp.* negative charges have been found at heights 5000-8000 km *resp.* 1500-3000 km. It is convenient to christen lower U shaped region as $\cap$ and the upper one as $\cup$. The negatively charged region feeds electrons to the aurora region and positively charged region sucks them back. There is however no consensus about how this kind of electric field is generated and how it could be stable.

A TGD inspired model for auroras

There are several poorly understood aspects related to the modelling of auroras. TGD approach provides new views to these problems. The following vision is perhaps the most plausible option discovered hitherto.

The basic condition is that cyclotron energies are above thermal energy. This allows to deduce lower bound the value of Planck constant assignable to the magnetic flux quanta. For $B_{end} = .2$ Gauss the cyclotron frequencies of electron and proton are.6 MHz and 300 Hz respectively and the formula $E = .41 \times 10^{-14} r \times (f/Hz)$, $r = \hbar/\hbar_0$, allows to deduce the estimate for the minimum value of Planck constant in terms of thermal energy and cyclotron frequency as

$$r = 2^{k_d} \quad \geq \quad \frac{E_{th}}{E} \quad , \quad \frac{E}{eV} = .41 \times 10^{-14} \times \frac{f_c}{Hz} \times \frac{B}{B_{end}} \quad . \tag{6.5.2}$$

Here power of two for r is assumed for simplicity. This gives the frequency as

$$\begin{aligned}
k_d(e) \quad &\geq \quad k_d(e,min) = 28.71 + 1.44 \times (log(\frac{E_{th}}{eV}) - log(\frac{B}{B_{end}}) \ \ (electron) \quad , \\
k_d(p) \quad &\geq \quad k_d(e,min) + 11 \ \ (proton) \quad , \\
k_d(I) \quad &\geq \quad k_d(p,min) + log(\frac{A}{Z}) \ \ (ion) \quad , \\
\frac{E_{th}}{eV} \quad &= \quad 2.22 \times 10^{-4} \times \frac{T}{K} \quad .
\end{aligned} \tag{6.5.3}$$

Both electronic and protonic supra currents flow for $k_d > k_d(e,min) + 11$. I refers to ion with charge Z and mass number A.

1. The ionosphere of Earth is at room temperature roughly below 85 km and at temperature 1200 K at upper layers. For B_{end} both electronic and protonic currents incould flow as supra currents if this condition is satisfied for temperature roughly room temperature for $k_d(p) = k_d(e) \geq 34$ below 85 km and for $k_d(p) = k_d(e) \geq 36$ at the upper layers.

2. The reconnection of field lines generalizes to reconnection of magnetic flux tubes. The large inertia of ions in reconnection process from solar wind flux tube can induce their leakage and subsequent transfer to the upper magnetic flux tube in reconnection process. This would accumulate negative charge to the lower and positive charge to the upper U shaped flux tube.

3. The rapid straightening of the lower U shaped flux tube behaving like rubber band provides the mechanism of acceleration and brings ions of solar wind to the ionosphere where the collision with the flux tubes of inner magnetosphere induces the collision of electrons and ions and generates auroras. The liberation of cyclotron energy of electrons in cyclotron transitions of Bose-Einstein condensate of Cooper pairs of electrons and protons, and possibly even of exotic O^+ ions makes possible ionization and electronic excitations of ions involved.

1. Could em currents flow along magnetic flux quanta of solar and Earth's magnetic field as supra currents?

The question is under what conditions the statement that charged particles move along the flux lines of Earth's magnetic field without appreciable dissipation translates in TGD framework to supra currents flowing along the flux tubes of Earth's magnetic field.

1. Consider first the flux tubes of solar wind. The solar wind is made of Hydrogen (95 per cent) and Helium (4 per cent) and Carbon, Nitrogen, Oxygen, Neon, Magnesium, Silicon and Iron ($\simeq$ 1 per cent). The temperature is $T \simeq 15$ eV. The magnetic field has strength $\sim$ 10 nT. Both proton and electron Cooper pairs cyclotron energies a would be above thermal energy at $k_d(p, min) \geq 56$ levels of dark matter hierarchy.

2. Consider next flux tubes in magnetotail. In magnetotail the field strength of Earth's magnetic field is around 30 nT in the lobes of the inner magnetosphere at the night side of Earth and temperature is around .5 eV (metabolic energy quantum again). This gives $k_d(p, min) = 50$ to be compared with $k_d(p, min) \geq 56$ for solar wind meaning that the reconnection process involves a phase transition changing the value of Planck constant.

3. An interesting question is whether Bose-Einstein condensates of exotic O^+ ions could be present near polar regions where field is stronger. What is known that cyclotron resonance frequencies of O^+ and H^+ ions appear in the frequency spectrum of electric fields in the aurora regions [F8]. This however requires only $k_d \geq 53$ since magnetic field is much stronger and near to $B_E = .5$ Gauss. What is interesting and perhaps of significance is that O^+ exotic ion would be the heaviest possible ion forming Bose-Einstein condensates and also the dominating one besides proton.

2. Radii of flux quanta

The gyroradius p_T/ZeB, where p_T is momentum transversal to B, of proton *resp.* electron of solar wind in the magnetotail is known to be about 700 km *resp.* 20 km whereas the radii of the magnetic flux tubes would be in the range in 10-100 micrometers for ordinary value of $\hbar$ and minimal magnetic flux. One must of course notice that currents at the boundaries of flux quanta allow to have arbitrary radii of flux quanta and this is the only sensible option in biomatter. One can consider several scaling laws for the the radius of the flux tube.

p-Adic length scale hypothesis suggests that scaling law could be $R \propto \sqrt{r}$, $r = \hbar/\hbar_0$. Also the radii of cyclotron orbits scale as $\sqrt{rn/eB}$, where n labels the cyclotron states. For B_{end} and for $r = 1$ the minimum radius would be about 5 μm. If the flux quantization in standard form is satisfied for B_{end} with $k_d(p, min) = 36$, the radius is about 1 m. For solar wind with $k_d(p, min) = 56$ and $B = 10$ nT this would give minimal radius of about 5 km. For tail with $B = 30$ nT and $k_d(p, min) = 50$ this would give 23 km which is slightly larger than electron's gyroradius. The value of gyroradius gives a condition on n if one assumes that the situation is semiclassical. For proton would have $n \simeq 926$ in tail.

The gyroradii of ions are smaller than the radii of flux tubes if one assumes standard flux quantization. If the radii of flux tubes are comparable than gyroradii, the ions can leak out from solar flux tube in the reconnection process. This would be essential for how the negatively and positively charged regions are generated in the reconnection process.

3. Reconnection mechanism

In TGD framework one can understand how reconnection can occur. The helical structure of the flux tubes implies that they can be in transversal direction to the average magnetic field and this means that flux tubes can meet each other in U-shaped manner. Thus the process of reconnection would be a genuine quantal and topological transition for which the flux quantization would be essential.

It seems natural to expect that the location of the reconnection region is determined from the requirement that the flux tubes of solar wind and Earth's magnetic field have same thickness so that also local magnetic fields have the same strength from flux quantization. In Maxwell's theory this corresponds to the fact that the two magnetic fields sum up to zero. The reconnection process should be also energetically favored.

4. Acceleration mechanism

One can regard Earth's magnetic field as a collection of magnetic flux tubes containing matter and analogous to rubber strings. For instance, the rotation of the magnetic flux tubes could be essential prerequisite for the stability of curved flux tubes. Also the idea about catapult action meaning that the reconnected U shaped magnetic flux tube in East-West plane, briefly $\cap$, rapidly straightens and becomes a flux tube in ionosphere and collides with flux tubes of ionosphere looks natural. $k_d \geq 56 \to k_d \geq 50$ phase transition would naturally accompany this process.

The collision of flux tubes would in turn induce the collision of ions and electrons inside them and generate auroras. For $k_d = 56$ at solar wind flux tubes the high energy scale $E_c = 15$ keV of the cyclotron energy states of electrons would induce ionization of atoms in the magnetic flux tubes and induce generation of visible light in atomic transitions of ions and also generation of X rays and perhaps even gamma rays. Even when the phase transition to $k_d \geq 50$ state occurs inside ionosphere, the cyclotron energy scale is 1.44 eV, which is in infrared. Here one must of course be careful to notice that this energy is just the minimum energy. One can think that the charged particles of solar wind end to large n cyclotron states at magnetotail and end up to lower energy states by emission of cyclotron radiation. Analogous collision of flux tubes could explain generation of X and gamma rays associated with lightnings.

5. Formation of return current and generation of strong voltage between reconnection region and aurora region

This picture allows also to understand why a return current from aurora region to $\cup$ is formed and what might cause the strong voltage of about 10^4 Volts between the top of $\cap$ and ionosphere.

The formation of the return current of electrons suggests the presence of closed electric field lines so that electric field would not be conservative. These closed field lines would correspond to closed structures formed from magnetic flux tubes carrying electric field. This means that there must be time varying magnetic flux through the surface , call it X^2, orthogonal to Earth's surface and extending from the aurora region in ionosphere to $\cup$. This is the case if the highly curve $\cap$ contracts (recall the rubber band analogy) to a relatively straight flux tube inside ionosphere in magnetic East-West direction. The change of the magnetic flux through X^2 would be the magnetic flux carried by this flux tube. Of course, several flux tubes might be involved.

The generalization of the flux quantization condition to time domain reads as

$$2e \int_0^T V dT = nr\hbar_0 \ ,$$

where T is the time during which flux tube traverses the boundary of ionosphere. The condition follows from Faraday's induction law and magnetic flux quantization, and relates the change of flux to the time and non-conservative voltage around flux loop. If n refers to the flux of single flux tube of Earth's magnetic field in which case it would have radius $R_n = \sqrt{n} \times 23$ km, $n \geq 1$ by the requirement that electron gyroradius is smaller than R_n.

This condition allows to estimate the value of T using the estimate $V = 10^4$ V [F3] for the voltage between recombination region and auroral region. For B_{tail} and $k_d = 56$ this gives $T = n \times 49$ s for the time during which the flux tube traverses the boundary of the ionosphere. In [F10] 200 s time scale is associated with the straightening process on basis of experimental data so that $n = 4$ suggests itself. This would support the idea about quantal process. This would mean radius 46 km safely above the electronic gyroradius 20 km. The velocity of straightening for the flux tube would be $v \sim 2R_1/T \simeq .25$ km/s.

7. Generation of regions of positive and negative charge

The proposed reconnection mechanism provides also insights to the mechanism leading to the generation of negative charge to the top of $\cap$ at height 1500-3000 km above Earth and positive charge to the bottom of $\cup$ at $5000 - 8000$ km above Earth [F10]. The formation of these regions can be indeed understood: due to the small inertia of electron Cooper pairs of solar wind and the fact that the electronic gyroradius 20 km is smaller than the radius of flux tube of Earth's magnetic field in magnetotail for $k_d = 56$, electrons are not expected to leak out of the flux tube in the reconnection process. Ions are however much more massive and their gyroradius (700 km for proton) is much larger than 20 km so that they are expected to leak out in the reconnection process and end up to $\cap$ thus providing it with a positive charge.

Auroras, meteors, and consciousness?

There are claims that auroras generate audible sounds [F16]. These sounds have not been detected by acoustic means. Magnetic sensory canvas hypothesis could explain this. The magnetic storms accompanying auroras should affect also our personal auditory canvases. In particular, Schumann resonances which could correspond either MEs parallel to the magnetic flux tubes or oscillations of the magnetic flux tubes, are excited. Higher Schumann resonances are in the audible range and could directly give rise to extrasensory perception of sounds.

There is also some other evidence for the sensory canvas hypothesis. Since 16th century it is known that also meteors produce audible sounds. What is mysterious that there is no time lag due to the propagation through the atmosphere. The explanation is that it is very low frequency em waves which propagate to Earth and generate sounds by interacting with the objects at the surface of Earth. Joined by the International Leonid Watch - Croatia (ILWC) project, a group of scientists presented the first instrumental detection of elusive electrophonic meteor sounds. In November 1998, the researchers from the Croatian Physical Society and the University of Kentucky organized an expedition to Mongolia to observe the anticipated Leonid meteor shower and shed some light on the phenomenon [F12]. The complete data analysis revealed two electrophonic (electronically detected) sounds that provided several important clues about the nature of this longstanding astronomical mystery. It became clear that sounds were created when the meteors were crossing night-time ionosphere. The existing theories cannot however completely explain the phenomenon. The energy of meteor does not seem to be high enough to invoke the electric fields needed to explain the electronically recorded sounds, and strangely enough, the frequencies are much lower than expected, in the region 20-40 Hz.

Magnetic flux quanta as carriers of the electromagnetic perturbations might allow a better understanding of the phenomenon. Perhaps the audible sounds, in contrast to the electronically recorded ones which seem to be of much lower frequency, are in fact generated by the direct perturbations of magnetic auditory canvas: this would explain why there is no lag due to the propagation through atmosphere. Electronically recorded sounds could be induced by the em perturbations propagating along magnetic flux ruvwa at Schumann frequencies and the mirrors might act as resonators amplifying the em fields (electrophonic sounds had frequency spectrum in the region of lowest Schumann frequencies). Notice that magnetic flux tubes of length shorter than Earth's circumference would give rise to higher resonance frequencies than Schumann frequencies.

There are also reports that seeing auroras can cause a loss of consciousness. This effect might not be only due to the depth of the aesthetic experience. The effects of magnetic storms on patients of mental hospitals are also well documented. If our sensory representations are indeed realized at magnetic flux tubes structures associated with Earth's magnetic field, one is led to ask whether the dissipative processes associated with auroras destroying ionic supra currents might indeed affect directly our consciousness, inducing even a loss of consciousness.

The magnetic flux tube structures associated with the sensory canvas could also experience the pressure of the solar wind and change their shape during night time. Also this might correlate with the fact that we usually sleep during night time and daytime consciousness differs from nighttime consciousness.

6.5.3 Lightnings, Sprites, Elves, And The Hypothesis Of Magnetic Sensory Canvas

In 1920s, the Scottish physicist C. T. R. Wilson predicted the existence of brief flashes of light high above large thunderstoms [D11, D11]. Almost 70 years later, Bernard Vonnegut of SUNY Albany realized that this prediction could be tested by studying the videos of Earth's upper atmosphere recorded by space shuttle astronauts. William Boeck and Otha Vaughan from NASA decided to look for the evidence and they indeed found it. Also John Winkler and his colleagues had serendipitously observed a flash in moonless night time skies over Minnesota in 1989. These findings inspired two field programs (led by Walter Lyons and Davis Sentman respectively) to study the new phenomena and it soon became clear that the flashes are in fact a common phenomenon in the mesosphere.

Sentman and Lyons found two broad classes of flashes [F15, F17]: sprites and elves. These short lived luminous phenomena are associated with large thunder storms called mesoscale convective systems often covering entire states in the Great Plains of the US in summertime. These migratory regions contain often regions of active convection adjacent to the regions of weaker stratiform convection. Ground flashes with a negative polarity (Earth surface corresponds to the negative electrode) dominate in the active convection regions whereas the less frequent but more energetic flashes with positive polarity (Earth surface corresponds to positive electrode) predominate in the stratiform regions. The great majority of sprites and elves are initiated by ground flashes of the latter type. Elves and very low frequency perturbations from electromagnetically pulsed sources are centered above vertical channels to ground whereas sprites lie above horizontally extensive spider lightnings in the lower portion of the stratiform cloud.

My own interest on these phenomena was stimulated by the article [F9] according to which neither the origin of the blue light accompanying sprites nor the fast rate for the development of sprites are well-understood. The obvious strategy is to find whether the notion of many-sheeted space-time could provide an improved understanding of these phenomena.

The notion of many-sheeted space-time is crucial for TGD based model of brain involving in an essential manner also the notion of the magnetic sensory canvas: the magnetic flux tube structures involved can have size comparable to Earth's size. An interesting question is whether one could somehow relate the notion of sensory magnetic canvas to the electromagnetic phenomena occurring in the atmosphere. Rather encouragingly, the basic dynamical time scales of lightnings, sprites and elves correspond to those associated with brain. This inspires some speculations about how magnetic bodies and atmospheric electromagnetic phenomena might relate.

Lightnings

A good summary about basic facts concerning lightnings [F14], sprites and elves can be found in Wikipedia [F2]. Lightnings are classified to positive and negative lightnings depending on whether the electron current is from ground to cloud or vice versa. The following brief summary gives a rough account of what happens in case of negative lightning for which electron current flows to ground.

An initial discharge, (or path of ionised air), called a "stepped leader", starts from the cloud and proceeds generally downward in a number of quick jumps, typical length 50 meters, but taking a relatively long time (200 milliseconds) to reach the ground. This initial phase involves a small current and is almost invisible compared to the later effects. When the downward leader is quite close, a small discharge comes up from a grounded (usually tall) object because of the intensified electric field.

Once the ground discharge meets the stepped leader, the circuit is closed, and the main stroke follows with much higher current. The main stroke travels at about 0.1 c and has high current for.1 m or so. It may persist for longer periods with lower current.

In addition, lightning often contains a number of restrikes, separated by a much larger amount of time, 30 milliseconds being a typical value. This rapid restrike effect was probably known in antiquity, and the "strobe light" effect is often quite noticeable.

Positive lightning does not generally fit the above pattern.

Positive lightnings are rare but more energetic. The typical voltages, electric fields, and durations of strikes involved with positive *resp.* negative lightnings are 1 GV, 10^5 V/m and 1 ms *resp.*.1 GV, 10^4 V/m and.1 ms. During positive lighting there is a huge amount of VLF and ELF radiations which implies that lightning induces effects in ionospheric scale.

The notions of leader emerging from cloud and streamer emerging from ground and meeting before the strike are well established. The development of leader means that air becomes conductive in a stepwise manner by ionization. Stepped leaders are associated with negative lightnings and dart leaders with positive lightnings. Lightnings are accompanied by X ray bursts with duration $< .1$ ms. with X ray energies up to few hundred keV. The bursts are presumably generated during stepped leader and dart leader phase. Also gamma ray bursts have been observed.

Runaway breakdown is a generally accepted mechanism in the theory for the formation of lightnings. It is assumed that cosmic ray strikes atmospheric molecular and releases extremely energetic electrons having enhanced free path length of tens of centimeters. Electrons are accelerated in the electric field of storm and ionize further molecules and initiate the runaway breakdown at higher which then proceeds downwards. Conductive path with a length of typically 50 m is created. There are however some problems. The rate for the strikes by cosmic rays having sufficient energy is $50/\mathrm{km}^2$ and too low to explain the number of lightnings during thunderstorm. Also the measured X ray burst intensity is only 5 per cent of the predicted value.

Sprites

Sprites come in several varieties and these complex structures have been dubbed with descriptive names like carrots, angles, jellyfish and A-bombs. The simplest sprites are so called C sprites which have transversal size of order 200 m and height of order 10 km and form structures resembling Fourth of July fireworks. The vertical extension of sprites can be as high as 60 km and there lower end is typically at the height of 30 km (for illustrations of sprites and elves see [F9]).

In Wikipedia [F14] sprites are characterized as follows.

Sprites are now well-documented electrical discharges that occur high above the cumulonimbus cloud of an active thunderstorm. They appear as luminous reddish-orange, neon-like flashes, last longer than normal lower stratospheric discharges (typically around 17 milliseconds), and are usually spawned by discharges of positive lightning between the cloud and the ground.

Sprites can occur up to 50 km from the location of the lightning strike, and with a time delay of up to 100 milliseconds. Sprites usually occur in clusters of two or more simultaneous vertical discharges, typically extending from 65 to 75 km above the earth, with or without less intense filaments reaching above and below. Sprites are preceded by a sprite halo that forms because of heating and ionisation less than 1 millisecond before the sprite.

The structure of sprite resembles that of a botanic tree consisting of roots (negative end), trunk and branches (positive end). This bi-directional structure of the sprite suggests two separate processes: the first process proceeds upwards and is followed by a second process proceeding downwards. The blue color of the lower part of the sprite (roots) is known to be due to the transitions of N_2^+ ions whereas the red color of the upper part is due to the transitions of N_2 molecules.

Wilson's theory suggests that the process associated with trunk and branches of the tree corresponds to a dielectric breakdown induced by the ionization of molecules by electrons flowing upwards in the electric field generated by the spider lightning. The dipole field associated with the lightning behaves as $1/z^3$ as function of height from the pancake like electronic reservoir located at the thunder cloud at height of order 10 km. Since the dielectric strength (the critical electric field causing the ionization of molecules) is proportional to the density of the molecules, which decreases exponentially with height, the dielectric breakdown is predicted to begin from higher heights above thunder cloud and cause a cascade like electron current.

The expression for the drift velocity of electron in an external electric field is obtained from the condition

$$\frac{m_e v^2}{2} = eEl \quad , \quad l = \frac{1}{n\sigma} \quad . \tag{6.5.4}$$

Here σ denotes the total scattering cross section for the scattering of electrons on molecules and l denotes the length of the average free path of electron. The condition simply states that the kinetic energy gained in the field between two interactions equals to the work done by the electric field on electron.

Ionization becomes possible when the kinetic energy is above the ionization energy E_{ion} of the molecules of the atmosphere. This condition determines the critical value of the electric field as

$$eE_{cr} = 2E_{ion}n\sigma \quad . \tag{6.5.5}$$

The critical value of the electric field is proportional to the density n of the molecules decreasing exponentially with height. The values of the dipole moment p characterizing the electric fields generated by lightnings range from 10 to more than 10^3 coulomb kilometers (for the convenience of the reader we notice that one coulomb corresponds roughly to 10^{19} electronic charges). Assuming the distance scale $z \sim 40$ km, dipole moment $p \sim 10^3$ Ckm, and collision cross section $\sigma \sim Angstrom^2$, one finds that the critical drift velocity is of the same order of magnitude as the observed velocity .1 c for the generation of sprite. In [F9] it has been stated that the predicted critical drift velocity tends to be too small.

The negative end of the sprite (roots) accompanied by blue light suggests that the N_2^+ ions created in the electronic ionization run downwards in this region. The mechanism leading to the transitions of N_2^+ ions generating blue light is most naturally the collisions of N_2^+ ions with N_2 molecules. This assumption conforms with the basic facts about sprite formation and structure: the intensity of the blue light is comparable to that of red light, the blue end of the sprite develops later than the red end, the blue emission is at the lower end of the sprite, and the branching of the lower end proceeds downwards. Note that the critical velocity for the ionization of N_2 molecules by collisions with N_2^+ molecules is proportional to $1/\sqrt{M(N_2)n}$ and thus considerably smaller than in case of electron for given values of n and E. This together with the larger density of N_2 molecules implies that the lower part of the sprite is generated more slowly.

A priori also sprites for which thunder cloud carries positive charge are possible. Only two cases of sprites associated of this kind have been found, and according to [F9] this asymmetry is not yet well-understood. A possible explanation is following. When cloud is negatively charged, the pancake like electronic reservoir located at the thunderstorm provides the seed electrons initiating the ionization cascade providing new current carrying electrons. When the cloud is positively charged, the electrons would propagate downwards from upper part of atmosphere to the direction in which drift velocity decreases. There are however no seed electrons now. There is however a reservoir of positive N_2^+ ions in thunder cloud and they might be able to generate the dielectric breakdown. It is quite possible that the typical seed density is simply too low for this in most cases. These infrequent sprites should have blue or pink-blue upper end ($N_2^+ - N_2$ collisions can also excite N_2 molecules) and should develop with much more slower rate.

If the collisions with the electrons were responsible for the transitions of N_2^+ ions (as believed in [F9]), the intensity of the blue light would be by several orders of magnitude weaker from the fact that the density of N_2^+ ions is of the same order as that of electrons from the requirement of overall charge neutrality, and from the fact that the density of N_2 ions is much higher than that of electrons (there are roughly 1 electron per 10 billion N_2 molecules [F9] at the upper portion of the sprite).

Elves

In Wikipedia [F14] elves are characterize in the following manner.

Elves often appear as a dim, flattened, expanding glow around 400 km (250 miles) in diameter that lasts for, typically, just one millisecond [7]. They occur in the ionosphere 100 km (60 miles) above the ground over thunderstorms. Their colour was a puzzle for some time, but is now believed to be a red hue. Elves were first recorded on another shuttle mission, this time recorded off French Guiana on October 7, 1990. Elves is a frivolous acronym for Emissions of Light and Very Low Frequency Perturbations From Electromagnetic Pulse Sources. This refers to the process by which the light is generated; the excitation of nitrogen molecules due to electron collisions (the electrons having been energized by the electromagnetic pulse caused by a positive lightning bolt).

Elves are thus a phenomenon occurring above ionosphere rather whereas sprites are ionospheric phenomena. This allows to understand why they occur for positive lightings (electrons flow from ground to cloud).

In case of elves the ionization mechanism differs from that for sprites. The radiation from the lightning decays with distance as $1/z$ and this guarantees that the threshold for the breakdown is exceeded as long as lightning current is sufficiently large. The observations show that there is a time lapse of order 10 ms between the lightning and the generation of elve: this lapse is consistent with the propagation of radiation with light velocity. Observations show that peak currents of 70 A or greater are required.

Electronic plasma frequency defined as

$$f_p^2 = \frac{n_e e^2}{m_e} \tag{6.5.6}$$

plays an important role in understanding the electromagnetic phenomena in atmosphere. Plasma frequency defines the cutoff frequency for waves which can propagate inside sprite: what this means is that frequencies lower than f_p are reflected. The observations about reflections of em waves on sprites show that f_p is in the range $2-25$ kHz which means that the density of electrons is in the range 10^4 to 10^6 cm^{-3}, somewhat more dilute than in aurora borealis and slightly above the electron concentration in the daytime E region of the ionosphere. VF and ELF em waves can propagate in the 80-90 km thick wave guide below ionosphere and sprite activity generates ELF waves, which are especially strong at Schumann resonance frequencies and serve as a global signature for them.

Dark matter hierarchy, lightnings, sprites, and elves

What is known about sprites and elves might be marginally understood in the framework of standard physics. The model for the leaders based on runaway breakdown induced by cosmic rays is however inconsistent with l empirical facts and dark Bose-Einstein condensates at the flux tubes of Earth's magnetic field provide an alternative model. This inspires the question whether dark matter hierarchy could manifests itself somehow in these phenomena. The first thing one can do is to look whether the time and length scales involved could be assigned with the basic scales of the dark matter hierarchy.

1. Time scales

Millisecond time scale seems to govern the dynamics of both lightnings, sprites and elves. The net time for the formation of stepped leader is about $\tau = 200$ ms and since length scale involved is 10 km this means that generation of single step corresponds to millisecond time scale $\tau_{step} = 1$ ms. Also the time scales of strikes are in millisecond scale: for instance, sprite halos appears millisecond before sprire, sprite typically last about 17 milliseconds, and elves last for 1 millisecond. Note that millisecond time scale assignable to d quark CD and 100 ms scale corresponds to electron.

The appearance of millisecond time scale for the main strike and appearance of re-strikes brings strongly in mind nerve pulse generation and nerve pulse sequences having similar time scales. Moreover, delta band of EEG resembles corresponding region of sferics and intense VLF and ELF radiation accompanies positive lightnings. The question is whether the similarity of time scales is a mere accident and whether lightnings could be regarded as sequences of scaled up nerve pulse like discharges involving kHz synchrony related to quark CDs and duration of 100 ms related to the CD of electron.

2. Length scales

One could consider at least half seriously the idea that the region between thunder cloud and Earth with thickness $L \sim 10$ km defining the length of leader is analogous to a scaled up dark variant of cell membrane. Similar idea could apply to the $L \sim 100$ km thick region between ionosphere and Earth surface. The length scale of single step about 50 m and its ratio to the distance $L = 10$ km is 2^{11} and could be understood in terms of the ratio τ/τ_{step}. One could wonder whether this ratio corresponds to proton-electron mass ratio.

1. Dark matter hypothesis implies that scaling proportional to r. The value of Planck constant can be deduced as $r = 2^{k_d} \simeq L/d$, where $d = 10$ nm denotes the thickness of the cell membrane. Note that $\sqrt{r}$ proportionality appropriate for p-adic length scales does not work

and these scales could be most naturally assigned with CDs. This gives the estimate $k_d = 40$ for thunder cloud and corresponds to Josephson frequency 640 Hz. For ionosphere one obtains $k_d = 47$, which corresponds to the 5 Hz Josephon frequency assigned with wake-up EEG. 50 km defining the maximum distance between sprites and lightning and would correspond to $k_d = 46$ and 10 Hz Josephson frequency with obvious meaning in biology.

2. The length scale 50 m for the step of the leader could correspond to $k_d = 18$ and Josephson frequency of 2.5 GHz.

3. The generation of lightning could proceed from $k_d = 18$ level to higher levels of dark matter hierarchy. This kind of hierarchical development could explain the sprites and elves as well as strong ELF and VLF is associated with positive lightnings as being to the fact that electron current proceeds upwards and can thus excite $k_d = 40$ ionospheric excitations (sprites) and $k_d = 47$ excitations (elves) above ionosphere.

3. Dark matter hierarchy and generation of leaders

Dark matter hierarchy suggests a new kind of mechanism initiating the development of leaders. The dissipation-free acceleration of cyclotron electron Cooper pairs and of ions at the flux tubes in strong electric field and transfer to the atomic space-time sheets could provide a mechanism generating the typically 50 meter long steps of step leaders. The energy of.5 MeV, which corresponds to electron rest mass, would be reached in a free acceleration of proton or electron Cooper pair in an electric field of $E = 10^4$ V/m associated with negative lightnings over distance 50 meters. This corresponds to electron rest mass so that also the generation of gamma rays could be understood. For dart leaders the same energy would be reached during 5 meter long free acceleration, which raises the question whether dart leaders are step leaders with shorter length of the basic step.

Electronic cyclotron energy scale for $k_d = 40$ level of dark matter hierarchy is about $E_c = 2$ keV. Therefore cyclotron photons emitted in the collisions of electron Cooper pairs at the magnetic flux tubes of Earth could be involved with the generation of highly energetic electrons which in turn induce runaway breakdown. This energy is perhaps too small to explain the energies of highest X rays and of gamma rays.

4. $k_d = 47$ dark matter level and the formation of sprites and elves

The too low drift velocity of electrons drifting to the trunk and branches of sprite from electron reservoir at the bottom of the cloud is a possible problem in the model for the formation of sprites. Almost dissipation free upwards directed acceleration of Cooper pairs of electrons at $k_d = 47$ magnetic flux tubes would allow much higher drift velocities since the free path of electron Cooper pair would be longer. This would reduce the critical value of the electric field and make the process faster.

The density of N_2 molecules is about $10^3/\mu m^3$ at the upper part of the sprite and one can consider the possibility that at least part of these molecules reside at the magnetic flux tubes of the dark counterpart B_{end} of the Earth's magnetic field B_E which is hypothesized to have the value $B_{end} = 2B_E/5$ on basis of the model explaining the effects of ELF em fields on vertebrate brain (see the appendix of [K22] and [K37]). One can even raise the question whether singly charged exotic N_2^+ ions (behaving like neutral atoms electronically) could be present and define cyclotron condensates. The downwards directed dissipation-free acceleration of N_2^+ exotic ions scattering from ordinary N_2^+ ions could induce the transitions of N_2^+ ions responsible for the blue color in the lower part of sprite.

In the case of elves the ionization mechanism is believed to involve radiation from lightning energizing electrons in turn exciting N_2 molecules. The effect would be stronger if Bose-Einstein condensate of exotic N_2^+ ions is excited coherently by the collisions with energized electronic Cooper pairs.

Atmospheric electromagnetic phenomena and consciousness

The hypothesis about magnetic sensory canvas should be related to experimental reality somehow. The electromagnetic phenomena (such as lightnings, auroras sprites, elves) in the atmospheric waveguide are indeed rather promising in this respect.

1. If the magnetic sensory canvas hypothesis holds true one has the right to expect that brain functioning and these electromagnetic phenomena should possess common time scales. Amazingly, the frequency spectra as well as typical durations for the lightnings, sprites and elves correspond to those associated with brain. The typical duration of lightning is about .1 seconds which is the fundamental time scale of sensory consciousness and defines the duration of the memetic code word. Sprites are generated during one millisecond and typically last 10-100 milliseconds. The spectrum of the spherics associated with the activity of lightnings is in the range 0-25 kHz: this follows from the fact that waves in this frequency range are reflected from ionosphere and propagate in the waveguide defined by the atmosphere. It is perhaps not an accident that this frequency range corresponds to the range of frequencies audible for human brain.

   It is also known that hippocampus, which is crucial for long term memories, contains highly ordered magnetite particles (private communication) and responds in complex ways to magnetic perturbations having frequencies in ELF range and amplitudes in picoTesla range. The amplitudes for the perturbations of Earth's magnetic field are also in picoTesla range in theta and alpha range of EEG frequencies. Also alpha waves generate a peak in MEG with amplitude of order picoTesla: presumably this peak corresponds to the lowest Schumann frequency. Also eyes generate static magnetic fields with strength of order 10 picoTesla.

   In consistency with the observations of Blackmann and others about the intensity and frequency windows for ELF em fields, these findings encourage to think that brain is indeed sensitive to the perturbations of Earth's magnetic field (note however that the electric fields in these experiments are typically of order $1-10$ V/m [J60] and roughly two orders of magnitude higher). This would mean also a sensitivity to the perturbations of the magnetic flux tube structures defining the hierarchy of magnetic bodies. These perturbation might directly affect conscious experience (not necessarily at our level of hierarchy) giving rise to effective extrasensory perceptions and the effects at the level of brain would represent a reaction to this kind of conscious experience.

2. There should be also interaction between brain and the electromagnetic phenomena in the atmosphere and Schumann resonances which characterize the perturbations of Earth's magnetic field should be of special importance. In fact, the third person aspect of conscious experience might be due to the cyclotron transitions at flux tubes assignable with dark parts of the Earth's magnetic field [K37]. Lightnings, sprites and elves indeed excite Schumann resonances known to affect strongly human consciousness [J57]. Furthermore, the shape of the frequency spectrum for sferics at delta frequencies resembles delta band of EEG [J41]. The generation of Schumann resonances might mean also a direct interaction with the magnetic sensory canvas and one cannot exclude the possibility that atmospheric phenomena could have role in signalling at the higher levels of self hierarchy. Perhaps the peak in MEG at alpha range results from this kind of interaction.

   There are typically few sprites per minute and they generate strong Schumann resonances. One can wonder whether sprites and/or the associated spider lightnings could have correlates at the level of EEG and neurophysiology and perhaps even affect conscious experience, say by causing changes in mood. It should be possible to check whether the EEGs of persons possibly located at different parts of globe display simultaneous correlates for sprites and lightnings.

3. One could go even further and try to test the fractality hypothesis. The ratio of length scales associated with pairs cell membrane-cell, cortex-brain and atmospheric waveguide-Earth are of same order of magnitude. This observation and Mother Gaia hypothesis encourages to consider the possibility that the atmosphere could in some sense be a scaled-up version of cortex, which in turn would be scaled-up version of the cell membrane. For instance, the transversal size of order 200 m of the smallest sprites (so called C sprites) would correspond to the micron length scale in brain length scale and thus the size of smallest neurons whereas this length scale corresponds to nanometer (DNA size scale) at neuronal level. The height of C sprites which is about 10 km corresponds to the length of about 50 microns which in turn reminds of the lengths of cortical neurons.

4. The geometric appearance of sprites brings in mind the geometry of neurons and one can even play with the thought that sprites and lightnings are associated with pre-existing electric flux tube structures in atmosphere so that lightnings, sprites and elves could be phenomena comparable to nerve pulse activity and graded potentials in brain. The geometric structures associated with sprites resembles the axonal and dendritic geometries for cortical neurons.

5. The most fascinating possibility is that sprites and elves are parts of magnetic bodies made temporarily visible. If so, then one could also consider the possibility that magnetic bodies form a self hierarchy analogous to that formed by monocellulars and increasingly complex multicellulars with cell being replaced with brain/physical body of organism. Various organisms would obviously form the lowest level of this self hierarchy and various levels of collective consciousness would be the electromagnetic analog of the multicellular life.

What auroras, tornadoes, ball lightnings, and cold fusion might have in common?

New physics due to a ground state, which is almost vacuum extremal could be the common demonimator of very large class of anomalous phenomena including auroras, tornadoes, ball lightnings, cold fusion, sonofusion, and last but not least - the entire biology!

If the density of the ions inside magnetic flux tubes is constant, garden hose instability for magnetic field suggests itself strongly. Similar instability might be associated with the flux quanta of the em and Z^0 magnetic fields associated with almost vacuum extremals (this is not assumed about sensory canvas) if they contain Z^0 ions which can be electromagnetically neutral. This kind of instability giving rise to spiral helices is the basic assumption in the TGD based model of tornadoes. This suggests super-conductivity analogous to that in the case of cell membrane for almost vacuum extremals, and since rotating systems probably involve also magnetic fields, phenomena analogous to auroras could be involved also now.

It is indeed well known that luminous phenomena resembling those accompanying ball lightnings [F14] are associated also with tornadoes [H10, H1, H29]). Edward Lewis introduces the notion of plasmoid to explain a wide range of phenomena including ball lightnings and tornadoes. He assigns plasmons even with cold fusion (the damage resulting to Palladium target in cold fusion resembles the traces caused by ball lightnings, [C7]) and super-conductivity (sic!). Although Lewis obviously over-generalizes the notion of plasmoid, one cannot deny that the concept has a strong theoretical appeal in it.

Also sonoluminescence [C1] could involve a phase transition to almost vacuum extremal ground state and the emission of visible light could come from the membrane like boundary layer. The UV photons could generate the observed high temperatures estimated to be as high as 20, 000 K, which corresponds to 2 eV photon energy. In this case the size scale of emitting region is in fact that of cell membrane. The proper identification of essense of plasmons could be the presence of membrane like structures with space-time sheets which are almost vacuum extremals. The presence of magnetic flux quanta far from vacuum extremal is also plausible if one takes the model of quantum biology as a starting point.

The findings of Lewis inspire the following basic ideas about the physics of many-sheeted space-time- some of the allready discussed.

1. The runaway mechanism for ions from the magnetic flux tubes could provide a general mechanism behind luminous phenomena like auroras, lightnings, ball lightnings, sprites, tornadoes, UFOS and various anomalous luminous phenomena such as earth lights in tectonically active areas. Plasmoids could result from Josephson currents alone via the leakage of dark highly energetic particles and dark Josephson photons to visible matter sector. Also analog of nerve pulse could be involved responsible for phenomena like lightning and elves. The un-identified source of energy in these phenomena might be the energy associated with the dark supra currents.

2. The break-down of the dark super-conductivity could be understood in terms of a supra current leakage to non-super-conducting space-time sheets caused by the inertia of the current carriers. The critical temperature could be determined as the temperature below which the join along boundaries bonds between super-conducting and non-conducting space-time sheets

are not formed. The temperature of super-conducting space-time sheets could be much more lower than this temperature but this is not necessary if high $\hbar$ dark matter is in question.

3. The Trojan horse mechanism of cold fusion [K97] involves the notion many-sheeted space-time in an essential manner. Perhaps the dark supra currents running at the magnetic flux tube space-time sheets not containing the nuclear Coulombic fields provide the means to circumvent the Coulomb barrier.

6.6 Appendix

6.6.1 Hierarchy Of Planck Constants And The Generalization Of The Notion Of Embedding Space

In the following the recent view about structure of embedding space forced by the quantization of Planck constant is summarized. The question is whether it might be possible in some sense to replace H or its Cartesian factors by their necessarily singular multiple coverings and factor spaces. One can consider two options: either M^4 or the causal diamond CD. The latter one is the more plausible option from the point of view of WCW geometry.

The evolution of physical ideas about hierarchy of Planck constants

The evolution of the physical ideas related to the hierarchy of Planck constants and dark matter as a hierarchy of phases of matter with non-standard value of Planck constants was much faster than the evolution of mathematical ideas and quite a number of applications have been developed during last five years.

1. The starting point was the proposal of Nottale [E6] that the orbits of the 4 inner planets correspond to Bohr orbits with Planck constant $\hbar_{gr} = GMm/v_0$ and outer planets with Planck constant $\hbar_{gr} = 5GMm/v_0$, $v_0/c \simeq 2^{-11}$. The basic proposal [K92] was that ordinary matter condenses around dark matter which is a phase of matter characterized by a non-standard value of Planck constant whose value is gigantic for the space-time sheets mediating gravitational interaction. The interpretation of these space-time sheets could be as magnetic flux quanta or as massless extremals assignable to gravitons.

2. Ordinary particles possibly residing at these space-time sheet have enormous value of Compton length meaning that the density of matter at these space-time sheets must be very slowly varying. The string tension of string like objects implies effective negative pressure characterizing dark energy so that the interpretation in terms of dark energy might make sense [K93]. TGD predicted a one-parameter family of Robertson-Walker cosmologies with critical or over-critical mass density and the "pressure" associated with these cosmologies is negative.

3. The quantization of Planck constant does not make sense unless one modifies the view about standard space-time is. Particles with different Planck constant must belong to different worlds in the sense local interactions of particles with different values of $\hbar$ are not possible. This inspires the idea about the book like structure of the embedding space obtained by gluing almost copies of H together along common "back" and partially labeled by different values of Planck constant.

4. Darkness is a relative notion in this framework and due to the fact that particles at different pages of the book like structure cannot appear in the same vertex of the generalized Feynman diagram. The phase transitions in which partonic 2-surface X^2 during its travel along X^3_l leaks to another page of book are however possible and change Planck constant. Particle (say photon -) exchanges of this kind allow particles at different pages to interact. The interactions are strongly constrained by charge fractionization and are essentially phase transitions involving many particles. Classical interactions are also possible. It might be that we are actually observing dark matter via classical fields all the time and perhaps have even photographed it [K111].

5. The realization that non-standard values of Planck constant give rise to charge and spin fractionization and anyonization led to the precise identification of the prerequisites of anyonic phase [K75]. If the partonic 2-surface, which can have even astrophysical size, surrounds the tip of CD, the matter at the surface is anyonic and particles are confined at this surface. Dark matter could be confined inside this kind of light-like 3-surfaces around which ordinary matter condenses. If the radii of the basic pieces of these nearly spherical anyonic surfaces - glued to a connected structure by flux tubes mediating gravitational interaction - are given by Bohr rules, the findings of Nottale [E6] can be understood. Dark matter would resemble to a high degree matter in black holes replaced in TGD framework by light-like partonic 2-surfaces with a minimum size of order Schwartschild radius r_S of order scaled up Planck length $l_{Pl} = \sqrt{\hbar_{gr} G} = GM$. Black hole entropy is inversely proportional to $\hbar$ and predicted to be of order unity so that dramatic modification of the picture about black holes is implied.

6. Perhaps the most fascinating applications are in biology. The anomalous behavior ionic currents through cell membrane (low dissipation, quantal character, no change when the membrane is replaced with artificial one) has a natural explanation in terms of dark supra currents. This leads to a vision about how dark matter and phase transitions changing the value of Planck constant could relate to the basic functions of cell, functioning of DNA and amino-acids, and to the mysteries of bio-catalysis. This leads also a model for EEG interpreted as a communication and control tool of magnetic body containing dark matter and using biological body as motor instrument and sensory receptor. One especially amazing outcome is the emergence of genetic code of vertebrates from the model of dark nuclei as nuclear strings [L3, K111], [L3].

The most general option for the generalized embedding space

Simple physical arguments pose constraints on the choice of the most general form of the embedding space.

1. The fundamental group of the space for which one constructs a non-singular covering space or factor space should be non-trivial. This is certainly not possible for M^4, CD, CP_2, or H. One can however construct singular covering spaces. The fixing of the quantization axes implies a selection of the sub-space $H_4 = M^2 \times S^2 \subset M^4 \times CP_2$, where S^2 is geodesic sphere of CP_2. $\hat{M}^4 = M^4 \backslash M^2$ and $\hat{CP}_2 = CP_2 \backslash S^2$ have fundamental group Z since the codimension of the excluded sub-manifold is equal to two and homotopically the situation is like that for a punctured plane. The exclusion of these sub-manifolds defined by the choice of quantization axes could naturally give rise to the desired situation.

2. CP_2 allows two geodesic spheres which left invariant by $U(2$ *resp.* $SO(3)$. The first one is homologically non-trivial. For homologically non-trivial geodesic sphere $H_4 = M^2 \times S^2$ represents a straight cosmic string which is non-vacuum extremal of Kähler action (not necessarily preferred extremal). One can argue that the many-valuedness of $\hbar$ is un-acceptable for non-vacuum extremals so that only homologically trivial geodesic sphere S^2 would be acceptable. One could go even further. If the extremals in $M^2 \times CP_2$ can be preferred non-vacuum extremals, the singular coverings of M^4 are not possible. Therefore only the singular coverings and factor spaces of CP_2 over the homologically trivial geodesic sphere S^2 would be possible. This however looks a non-physical outcome.

   (a) The situation changes if the extremals of type $M^2 \times Y^2$, Y^2 a holomorphic surface of CP_3, fail to be hyperquaternionic. The tangent space M^2 represents hypercomplex sub-space and the product of the Kähler-Dirac gamma matrices associated with the tangent spaces of Y^2 should belong to M^2 algebra. This need not be the case in general.

   (b) The situation changes also if one reinterprets the gluing procedure by introducing scaled up coordinates for M^4 so that metric is continuous at $M^2 \times CP_2$ but CDs with different size have different sizes differing by the ratio of Planck constants and would thus have only piece of lower or upper boundary in common.

3. For the more general option one would have four different options corresponding to the Cartesian products of singular coverings and factor spaces. These options can be denoted by

$C-C$, $C-F$, $F-C$, and $F-F$, where C (F) signifies for covering (factor space) and first (second) letter signifies for CD (CP_2) and correspond to the spaces $(\hat{CD}\hat{\times}G_a)\times(\hat{CP_2}\hat{\times}G_b)$, $(\hat{CD}\hat{\times}G_a)\times\hat{CP_2}/G_b$, $\hat{CD}/G_a\times(\hat{CP_2}\hat{\times}G_b)$, and $\hat{CD}/G_a\times\hat{CP_2}/G_b$.

4. The groups G_i could correspond to cyclic groups Z_n. One can also consider an extension by replacing M^2 and S^2 with its orbit under more general group G (say tetrahedral, octahedral, or icosahedral group). One expects that the discrete subgroups of $SU(2)$ emerge naturally in this framework if one allows the action of these groups on the singular sub-manifolds M^2 or S^2. This would replace the singular manifold with a set of its rotated copies in the case that the subgroups have genuinely 3-dimensional action (the subgroups which corresponds to exceptional groups in the ADE correspondence). For instance, in the case of M^2 the quantization axes for angular momentum would be replaced by the set of quantization axes going through the vertices of tetrahedron, octahedron, or icosahedron. This would bring non-commutative homotopy groups into the picture in a natural manner.

About the phase transitions changing Planck constant

There are several non-trivial questions related to the details of the gluing procedure and phase transition as motion of partonic 2-surface from one sector of the embedding space to another one.

1. How the gluing of copies of embedding space at $M^2\times CP_2$ takes place? It would seem that the covariant metric of CD factor proportional to $\hbar^2$ must be discontinuous at the singular manifold since only in this manner the idea about different scaling factor of CD metric can make sense. On the other hand, one can always scale the M^4 coordinates so that the metric is continuous but the sizes of CDs with different Planck constants differ by the ratio of the Planck constants.

2. One might worry whether the phase transition changing Planck constant means an instantaneous change of the size of partonic 2-surface in M^4 degrees of freedom. This is not the case. Light-likeness in $M^2\times S^2$ makes sense only for surfaces $X^1\times D^2\subset M^2\times S^2$, where X^1 is light-like geodesic. The requirement that the partonic 2-surface X^2 moving from one sector of H to another one is light-like at $M^2\times S^2$ irrespective of the value of Planck constant requires that X^2 has single point of M^2 as M^2 projection. Hence no sudden change of the size X^2 occurs.

3. A natural question is whether the phase transition changing the value of Planck constant can occur purely classically or whether it is analogous to quantum tunnelling. Classical non-vacuum extremals of Chern-Simons action have two-dimensional CP_2 projection to homologically non-trivial geodesic sphere S^2_I. The deformation of the entire S^2_I to homologically trivial geodesic sphere S^2_{II} is not possible so that only combinations of partonic 2-surfaces with vanishing total homology charge (Kähler magnetic charge) can in principle move from sector to another one, and this process involves fusion of these 2-surfaces such that CP_2 projection becomes single homologically trivial 2-surface. A piece of a non-trivial geodesic sphere S^2_I of CP_2 can be deformed to that of S^2_{II} using 2-dimensional homotopy flattening the piece of S^2 to curve. If this homotopy cannot be chosen to be light-like, the phase transitions changing Planck constant take place only via quantum tunnelling. Obviously the notions of light-like homotopies (cobordisms) are very relevant for the understanding of phase transitions changing Planck constant.

How one could fix the spectrum of Planck constants?

The question how the observed Planck constant relates to the integers n_a and n_b defining the covering and factors spaces, is far from trivial and I have considered several options. The basic physical inputs are the condition that scaling of Planck constant must correspond to the scaling of the metric of CD (that is Compton lengths) on one hand and the scaling of the gauge coupling strength $g^2/4\pi\hbar$ on the other hand.

1. One can assign to Planck constant to both CD and CP_2 by assuming that it appears in the commutation relations of corresponding symmetry algebras. Algebraist would argue that

Planck constants $\hbar(CD)$ and $\hbar(CP_2)$ must define a homomorphism respecting multiplication and division (when possible) by G_i. This requires $r(X) = \hbar(X)\hbar_0 = n$ for covering and $r(X) = 1/n$ for factor space or vice versa.

2. If one assumes that $\hbar^2(X)$, $X = M^4$, CP_2 corresponds to the scaling of the covariant metric tensor g_{ij} and performs an over-all scaling of H-metric allowed by the Weyl invariance of Kähler action by dividing metric with $\hbar^2(CP_2)$, one obtains the scaling of M^4 covariant metric by $r^2 \equiv \hbar^2/\hbar_0^2 = \hbar^2(M^4)/\hbar^2(CP_2)$ whereas CP_2 metric is not scaled at all.

3. The condition that $\hbar$ scales as n_a is guaranteed if one has $\hbar(CD) = n_a\hbar_0$. This does not fix the dependence of $\hbar(CP_2)$ on n_b and one could have $\hbar(CP_2) = n_b\hbar_0$ or $\hbar(CP_2) = \hbar_0/n_b$. The intuitive picture is that n_b- fold covering gives in good approximation rise to n_an_b sheets and multiplies YM action action by n_an_b which is equivalent with the $\hbar = n_an_b\hbar_0$ if one effectively compresses the covering to $CD \times CP_2$. One would have $\hbar(CP_2) = \hbar_0/n_b$ and $\hbar = n_an_b\hbar_0$. Note that the descriptions using ordinary Planck constant and coverings and scaled Planck constant but contracting the covering would be alternative descriptions.

   This gives the following formulas $r \equiv \hbar/\hbar_0 = r(M^4)/r(CP_2)$ in various cases.

	$C-C$	$F-C$	$C-F$	$F-F$
r	n_an_b	$\frac{n_a}{n_b}$	$\frac{n_b}{n_a}$	$\frac{1}{n_an_b}$

Preferred values of Planck constants

Number theoretic considerations favor the hypothesis that the integers corresponding to Fermat polygons constructible using only ruler and compass and given as products $n_F = 2^k \prod_s F_s$, where $F_s = 2^{2^s} + 1$ are distinct Fermat primes, are favored. The reason would be that quantum phase $q = exp(i\pi/n)$ is in this case expressible using only iterated square root operation by starting from rationals. The known Fermat primes correspond to $s = 0, 1, 2, 3, 4$ so that the hypothesis is very strong and predicts that p-adic length scales have satellite length scales given as multiples of n_F of fundamental p-adic length scale. $n_F = 2^{11}$ corresponds in TGD framework to a fundamental constant expressible as a combination of Kähler coupling strength, CP_2 radius and Planck length appearing in the expression for the tension of cosmic strings, and the powers of 2^{11} was proposed to define favored as values of n_a in living matter [K37].

The hypothesis that Mersenne primes $M_k = 2^k - 1$, $k \in \{89, 107, 127\}$, and Gaussian Mersennes $M_{G,k} = (1 + i)k - 1$, $k \in \{113, 151, 157, 163, 167, 239, 241..\}$ (the number theoretical miracle is that all the four scaled up electron Compton lengths $L_e(k) = \sqrt{5}L(k)$ with $k \in \{151, 157, 163, 167\}$ are in the biologically highly interesting range 10 nm-2.5 μm) define scaled up copies of electro-weak and QCD type physics with ordinary value of $\hbar$ and that these physics are induced by dark variants of corresponding lower level physics leads to a prediction for the preferred values of $r = 2^{k_d}$, $k_d = k_i - k_j$, and the resulting picture finds support from the ensuing models for biological evolution and for EEG [K37]. This hypothesis - to be referred to as Mersenne hypothesis - replaces the rather ad hoc proposal $r = \hbar/\hbar_0 = 2^{11k}$ for the preferred values of Planck constant.

How Planck constants are visible in Kähler action?

$\hbar(M^4)$ and $\hbar(CP_2)$ appear in the commutation and anti-commutation relations of various superconformal algebras. Only the ratio of M^4 and CP_2 Planck constants appears in Kähler action and is due to the fact that the M^4 and CP_2 metrics of the embedding space sector with given values of Planck constants are proportional to the corresponding Planck. This implies that Kähler function codes for radiative corrections to the classical action, which makes possible to consider the possibility that higher order radiative corrections to functional integral vanish as one might expect at quantum criticality. For a given p-adic length scale space-time sheets with all allowed values of Planck constants are possible. Hence the spectrum of quantum critical fluctuations could in the ideal case correspond to the spectrum of $\hbar$ coding for the scaled up values of Compton lengths and other quantal lengths and times. If so, large $\hbar$ phases could be crucial for understanding of quantum critical superconductors, in particular high T_c superconductors.

6.6.2 Cyclotron Frequencies And Larmor Frequencies

The appendix emphasizes the difference between the endogenous magnetic field B_{end} explaining the effects of ELF em fields on vertebrate brain and Earth's magnetic field B_E and lists cyclotron and Larmor frequencies of some ions for B_{end}.

The relationship between the values of the endogenous magnetic field and the Earth's magnetic field

For years I erratically believed that the magnitude of the magnetic field assignable to the biological body is $B_E = .5$ Gauss, the nominal value of the Earth's magnetic field. Probably I had made the calculational error at very early stage when taking Ca^{++} cyclotron frequency as a standard. I am grateful for Bulgarian physicist Rossen Kolarov for pointing to me that the precise magnitude of the magnetic field implying the observed 15 Hz cyclotron frequency for Ca^{++} is .2 Gauss and thus slightly smaller than the minimum value.3 Gauss of B_E. This value must be assigned to the magnetic body carrying dark matter rather than to the flux quanta of the Earth's magnetic field. This field value corresponds roughly to the magnitude of B_E at distance 1.4R, R the radius of Earth.

Dark matter hierarchy leads to a detailed quantitative view about quantum biology with several testable predictions [K37] . The applications to living matter suggests that the basic hierarchy corresponds to a hierarchy of Planck constants coming as $\hbar(k) = \lambda^k(p)\hbar_0$, $\lambda \simeq 2^{11}$ for $p = 2^{127-1}$, $k = 0, 1, 2, ...$ [K37]. Also integer valued sub-harmonics and integer valued sub-harmonics of λ might be possible. Each p-adic length scale corresponds to this kind of hierarchy. Number theoretical arguments suggest a general formula for the allowed values of λ [K40] as $\lambda = n$ where n characterizes the quantum phase $q = exp(i\pi/n)$ characterizing Jones inclusion [K118]. The values of n for which quantum phase is expressible using only iterated square root operation are number theoretically preferred and correspond to integers n expressible as $n = 2^k \prod_n F_{s_n}$, where $F_s = 2^{2^s} + 1$ is Fermat prime and each of them can appear only once. $n = 2^{11}$ obviously satisfies this condition. The lowest Fermat primes are $F_0 = 3, F_1 = 5, F_2 = 17$. The prediction is that also n-multiples of p-adic length scales are possible as preferred length scales. The unit of magnetic flux scales up as $h_0 \rightarrow h = nh_0$ in the transition increasing Planck constant: this is achieved by scalings $L_e(k) \rightarrow nL_e(k)$ and $B \rightarrow B/n$.

$B = .2$ Gauss would correspond to a flux tube radius $L = \sqrt{5/2} \times L_e(169) \simeq 1.58 L_e(169)$, which does not correspond to any p-adic length scale as such. $k = 168 = 2^3 \times 3 \times 7$ with $n = 5$ would predict the field strength correctly as $B_{end} = 2B_E/5$ and predict the radius of the flux tube to be $r = 18$ μm, size of a large neuron. However, $k = 169$ with flux $2h_5$ would be must more attractive option since it would give a direct connection with Earth's magnetic field. Furthermore, the model for EEG forces to assume that also a field $B_{end}/2$ must be assumed and this gives the minimal flux h_5. Note that $n = 5$ is the minimal value of n making possible universal topological quantum computation with Beraha number $B_n = 4cos^2(\pi/n)$ equal to Golden Mean [K6].

An interesting working hypothesis is that B_{end} is the dark companion of the Earth's magnetic field and that the ratio $B_{end} = 2B_E/5$ holds true in the entire magnetosphere as a time average so that B_{end} would define what might be called the dark magnetosphere of Earth.

Table of cyclotron frequencies and magnetic frequencies

A detailed study of the cyclotron frequencies demonstrates that they indeed seem to correspond to important EEG frequencies. The cyclotron frequencies associated with other singly ionized atoms can be obtained by the formula

$$f = \frac{A}{20} \times f(Ca^{2+}) \qquad f(Ca^{2+}) \simeq 15\ Hz \ . \tag{6.6.1}$$

Here the strength of the endogenous magnetic field B_{end} is assumed to be .2 Gauss $= 2 \times 10^{-5}$ Tesla. The

Table 6.6 lists cyclotron frequencies and their lowest multiples for some of the most important ions.

Elementary particle	f_1/Hz	J	f_L/Hz
e	5.6×10^5	1/2	2.8×10^5
p	300	1/2	419
Bosonic ions			
^6Li	50.1	1	88.3
O^{2-}	37.4	0	0
Mg^{++}	25.0	0	0
Ca^{++}	15.0	0	0
Mn^{2+}	11.4	5/2	520
Fe^{2+}	10.8	0	0
Co^{2+}	10.0	7/2	695
Zn^{2+}	9.4	0	0
Se^{2-}	7.6	0	0
Fermionic ions			
$^7Li^+$	42.9	3/2	489
N^+	21.4	1	60.6
F^-	15.8	1/2	395
Na^+	13.0	3/2	333
Al^+	11.1	5/2	546
Si^+	10.7	0	0
P^+	9.7	1/2	170
S^-	9.4	0	0
Cl^-	8.5	3/2	130
K^+	7.5	3/2	58.5
Cr^-	5.7	3/2	71.1
Cu^+	4.8	3/2	333.9
Ag^+	2.8	1/2	17
I^+	2.4	5/2	420
Au^+	1.5	3/2	21

Table 6.6: The first column gives cyclotron frequency in cycles per second for some ions in the endogenous magnetic field $B_{end} = 2B_E/5 = .2$ Gauss explaining the effects of ELF em fields on vertebrate brain ($B_E = .5$ Gauss denotes the nominal of the Earth's magnetic field). The remaining columns give spin or nuclear spin and Larmor frequency f_L.

Part II

QUANTUM ANTENNA HYPOTHESIS

Chapter 7

Quantum Antenna Hypothesis

7.1 Introduction

One of the basic problems faced by the quantum theories of consciousness is to understand how macroscopic quantum coherence in the brain is realized. Bose-Einstein condensates and coherent states are believed to be crucial in this respect but the great problem is how macroscopic quantum phases could be realized in the wetty, noisy and hot environment provided by brain. In TGD framework the notion of many-sheeted space-time provides a solution to this basic problem. Furthermore, the notion of self as a subsystem able to remain un-entangled is consistent with the fact that macroscopic quantum phases behave like quantum particles. The general views about macroscopic quantum phases predicted by TGD and about their role with regards to consciousness is described in previous chapters. This chapter is devoted to coherent and Bose-Einstein condensed photons which are crucial in the quantum models of brain consciousness relaying on microtubules and seem to be associated with linear structures also in TGD framework. These linear structures include not only microtubules but also axons, DNA and proteins and most of the considerations to follow are quite general and by no means restricted to microtubules.

7.1.1 Massless Extremals And Quantum Antenna Hypothesis

The purpose of this chapter is a more detailed formulation of the quantum antenna hypothesis stating that microtubules generate a macroscopic coherent state of photons. The so called massless extremals are a very general class of zero action non-vacuum extremals of both the Kähler action and the effective action and differentiate clearly between TGD and standard gauge theories, in particular QED. Massless extremals describe the propagation of massless gauge fields in single preferred direction. The polarization for given values of transversal coordinates has a fixed direction. Linear superposition is not possible.

Topological field quantization assigns to each quantum notion its classical counterpart and a very attractive identification of the massless extremals is as the classical counterparts of massless classical quanta such as photons and gravitons. Even the classical counterparts of the virtual particles make sense: in particular, negative energy photons represented by annihilation part of the free photon field seem to have geometric representation as negative energy massless extremals.

Massless extremals (ME) of the effective action can indeed generate coherent states of photons and gravitons.

1. ME:s are characterised by light like vacuum Kähler current J_K. In general but not always this implies light-like em current J_{em} and the standard coupling to the quantized photon field generates a coherent state of photons.

2. The geometry of the 3-surface in question is most naturally cylindrical and microtubules (as also DNA, proteins, etc..) indeed possess this kind of geometry. There are sharp resonances at frequencies $\omega = n2\pi/L$, where L is the length of the cylindrical 3-surface (say a space-time sheet associated with a microtubule). The BE condensates for the resonance frequency photons provide means of communication for the neuron society and could orchestrate microtubules to form a single macroscopic quantum system. One could also consider

the possibility that nerve pulse patters are coded to vacuum currents and in turn coded to patterns of coherent photons. In fact, the model of memetic code leads to the identification of nerve pulse/no nerve pulse as Boolean statement true/false. The coding of the nerve pulse patterns to the patterns of vacuum currents of axonal microtubules could occur naturally. The vacuum currents associated with the radial neuronal microtubules could communicate nerve pulse patterns to cell nucleus and the effects of the anesthetics on neuronal microtubules could mean the cutting of this communication line.

A necessary condition for the macroscopic quantum coherence is the phase locking of the vacuum currents associated with different microtubules. Join along boundaries bonds connecting the massless extremals to a larger space-time sheet serving as a common pacemaker could make possible the phase locking.

7.1.2 Evidence

This picture suggests that microtubules could act as senders and receivers of a coherent light and that visual consciousness should be closely related with the microtubules in accordance with the general philosophy already described. There is indeed some experimental support for identifying the coherent states of photons as associated with vision. It is known that some monocellulars possess elementary vision based on the microtubules [I61]. The length distribution of the microtubules in the rods and cones of the eye is concentrated in the region of the visible wavelengths. Insects are known to perceive certain chemical compounds (such as pheromones) by the maser like emission of infrared light by these chemical compounds [I86]. Also human nose contains so called vomeronasal organ which seems to give rise to an additional unconscious sense of odors with social and sexual meaning. Interesting hypothesis is that also this vision is based on infrared vision.

There is quite unexpected connection with the phenomenon of sonoluminescence suggesting that liquids contain structures of size of order microtubule diameter and that the highly synchronized light flash emitted in the sonoluminescence results from the condensation of water vapor to liquid involving generation of $k = 149$ space-time sheets from $k = 151$ space-time sheets by p-changing phase transition and subsequent creation of light-like vacuum currents at almost empty $k = 151$ space-time sheets leading to the emission of the flash of coherent light.

An additional support for the quantum antenna hypothesis comes from the quite recently observed anomalous dissociation of water molecules to hydrogen and oxygen in room temperature in presence of catalyst and stirring of the liquid. Usually the reaction is driven by thermal photons at temperature of order 3300 K. A possible explanation is that the Z^0 magnetic flux tubes created by the rotating nuclear Z^0 charge are accompanied by space-time sheets carrying light like vacuum currents generating coherent photons, which in turn drive the dissociation reaction.

Biefeld-Brown effect is one of the oldest poorly understood anomalous effects [H4, H12, H19]. What happens is that charged capacitor gains center of mass momentum in the direction orthogonal to the plane of the capacitor plates. Antigravity effect caused by the redistribution of gravitational and/or Z^0 fluxes of the capacitor between various space-time sheets could explain some aspects of the effect. The generation of negative energy space-time sheet with net momentum associated with classical em fields could be also involved with the effect. So called “massless extremals” are optimal candidates for this purpose. This mechanism might be applied by bio-systems to generate coherent motions.

7.1.3 Quantum Antenna Hypothesis And Brain Consciousness

The identification of macroscopic quantum phases possibly serving as quantum correlates of some qualia does not yet help much in understanding brain consciousness. Brain as a neuron society, brain as a music instrument or even entire orchestra and the notion of neural window are metaphors which have served as guidelines in the attempts to guess the general architecture of brain consciousness and might help also the reader to better understand the considerations to follow.

Brain as a neuron society metaphor

The brain as a society of conscious neurons metaphor has surprisingly nontrivial consequences. In particular, a plausible and testable hypothesis for the physical correlates of the sensory qualia becomes possible.

1. Brain as a society of conscious neurons metaphor suggests that our sensory qualia must have a reduction to the neuronal level. For instance, this could mean that our sensory experiences correspond to the sensory experiences associated with the large coherently firing neuron gap junction connected neuron groups in brain.

2. Conscious neurons must be able to communicate their conscious experiences to their fellow neurons. The simplest way to achieve this is to regenerate the original sensory experience to be communicated by sending a message which creates the stimulus resembling the stimulus giving rise to the original sensory experience.

An attractive idea is that the massless extremals (MEs) associated with the microtubules and other linear structures are for the neuron society what radio receivers and stations are for us. Perhaps the idea about the information society at neuronal level does not look so far fetched if one recalls that a communication based on the genetic code takes place already at DNA-protein level. Furthermore, if Nature has invented a communication by means of a coherent light, it probably has invented also the use of several bandwidths by using several microtubule lengths so that very sophisticated communication systems could exists in brain.

Brain as a society of neurons hypothesis has close relationship to other hypothesis with very similar content. Global workspace hypothesis [J18] states essentially that mass media type communication available for large numbers of neurons plays crucial role in the functioning of conscious brain: coherent light is ideal for this purpose. Also brain as hologram idea [J64, J52]. which is abstracted to neuronal window idea in TGD framework, states that some kind of mass media type communication occurs.

The notion of neural window

The idea of neural window suggests that secondary sensory organs see either the classical em field or the coherent light generated by the mind-like space-time sheets representing the objects of the perceptive field, which can be associated with the primary sensory organ or with the secondary sensory organs in thalamus and cortex. This secondary vision, which could make possible imagination in or all sensory modalities, would be made possible by the coherent photons suffered Bose-Einstein condensation on space-time sheets associated with microtubules or with axons (several space-time sheets might be involved) and serving as wave guides. Massless extremals allow to translate the notion of neural window to the notion of quantum hologram.

Music metaphor

Music metaphor which states that each neuron gives rise to characteristic sensory experience like string of piano gives rise to single note, gives strong constraint on the neuronal window idea. The massless extremal associated with axon corresponds to definite axon dependent frequency. In fact, in the proposed model for the quantum correlates of the sensory qualia [K41] sensory qualia are characterized by some frequency of BE condensed photons besides a pattern of cyclotron frequencies.

A related catching metaphor is to regard groups of parallel axonal microtubules as an orchestra producing light instead of sound with various frequencies. The interior containing the light-like em current would be the instrument and the note produced by single tubule would be a superposition of the frequencies $n\omega_0$, $\omega_0 = 2\pi/L$. The Fourier spectrum of the massless extremal would define the characteristics of the instrument. Of course, in long time scales microtubule could vary its length and achieve more impressive performances than single note samba. A good candidate for the player is the microtubule surface controlling the amplitude of the quantum photon field emitted by the interior by modulating the light-like current in the interior.

Brain as an associative net

The previous metaphors are consistent with the basic view about brain is as associative net such that conscious associations at neural level correspond to conscious experiences of presynaptic neurons associated with the experience of the postsynaptic neuron. The experiences of given neuron is always the same and only its intensity varies so that brain is indeed like a music instrument or orchestra. The intensity of experience is coded by the pattern of nerve pulses. The hypothesis about memetic code states following things. Nerve pulse/no nerve pulse corresponds to true/false Boolean statement; the codons of the memetic code consist of 126 bits and have total duration of order .1 seconds, the duration of our cognitive sub-self; single bit corresponds to a duration of order one millisecond, the duration of nerve pulse; codons are represented by temporal sequences of cognitive neutrino pairs to which nerve pulse sequences are coded; cognitive neutrino pairs are in turn coded to conscious experiences in many-to-one way by a unique code analogous to that coding mRNA sequences to polypeptides.

7.1.4 Relationship Of TGD Approach With Microtubular Approach

The role of the microtubules (for a nice introduction see [J28]) is believed to be also important for brain consciousness. In TGD framework however microtubules are only one, rather low-lying, although certainly important, level of the self-hierarchy and microtubular consciousness is not expected to correspond to our consciousness directly. In fact, the identification of our sub-selves (mental images) as "ELF selves" having as their geometrical correlates topological field quanta of em field with size of Earth, supported by various experimental data about the effects of ELF (extremely low frequency) em fields on brain and correlating our sub-selves with certain EEG frequencies, could not be philosophically farther from the reductionistic identification of microtubules as seat of our consciousness proposed by Penrose and Hameroff [J70].

Fröhlich condensates [I66] and microtubular Bose-Einstein condensates of photons have been proposed as the relevant macroscopic quantum phases in the microtubular theory of consciousness. Also in TGD framework macroscopic quantum phases are crucial and serve as quantum correlates of sensory qualia. The basic problem of these theories is how to preserve macroscopic quantum coherence over a time interval of order .1 seconds characterizing our consciousness. In In TGD framework the wake-up time of the microtubular selves (time which they are able to stay p-adically unentangled) of about 10^{-16} seconds typically, is not a problem since microtubular selves are not our immediate sub-selves.

The notion of many-sheeted space-time allows TGD counterparts of both Fröhlich condensates and microtubular photon BE condensates as condensates associated not only with microtubules.

1. Wormhole contacts are unavoidable element of the many-sheeted space-time concept. Wormhole contacts behave in many respects like charged particles and are described by a complex order parameter and it makes sense to speak about wormhole super conductivity. The connection with Fröhlich's condensate comes as follows. Electric fields penetrate from one space-time sheet to another via wormhole contacts carrying quantized fluxes. Thus the normal component of electric field is essentially the density of wormhole charge given by the modulus squared for the order parameter of the wormhole BE condensate. Vacuum polarization of the space-time sheet amounts to the generation of wormhole BE condensates of opposite gauge flux on the two sides of the polarized space-time sheet. In a well defined sense wormhole contact order parameter is square root of the order parameter of Fröhlich condensate.

2. Living matter behaves as liquid crystal and the electret nature of liquid crystals is crucial for many-sheeted ionic flow equilibrium since the weak but coherent electric fields make possible ohmic currents at atomic space-time sheets transforming to supra currents at superconducting space-time sheets.

3. Vacuum gauge fields with non-vanishing gauge currents are a generic phenomenon in TGD and not possible in standard theories. These c-number currents automatically generate quantum coherent states of photons and gravitons via their coupling to the corresponding quantized boson fields. Massless extremals are ideal in this respect since the generation of coherent

photons by the light-like vacuum current occurs resonant like way. Very importantly, massless extremals allow BE condensates of photons in the direction of the light-like vacuum current. This means that massless extremals can serve both as receiving and sending quantum antennae.

7.1.5 MEs And Information Molecules

The notion of information molecule is central for the understanding of biological control. There are however several difficult questions related to the notion of information molecule. TGD inspired view about biocontrol and coordination suggests a general answer to these questions and leads to a general model of biological control based on both MEs and information molecules with massless extremals (MEs) serving as actual information carriers initiating self-organization processes whereas information molecules are in the role analogous to that of computer password.

7.1.6 MEs And Quantum Holography

One can generalize the original solution ansatz for MEs by introducing what might be called local light cone coordinates for M^4_+. Boundary conditions for MEs are satisfied if the boundaries of MEs are light-like 3-surfaces, and thus have the same miraculous conformal properties as the boundary of the future light cone. In fact, the light-likeness of the boundaries of M^4 like space-time sheets provide a universal ways to satisfy boundary conditions for field equations.

The superconformal and super-symplectic symmetries can be used to generalize the construction of the configuration space geometry to take into account the classical non-determinism of Kähler action. Quantum holography in the sense of the quantum information theory allows to interpret MEs both as receiving and sending quantum antennae as well as dynamical holograms with light-like vacuum currents defining the counterpart of the diffraction grating, and making possible the teleportation of quantum em fields. The superconformal and super-symplectic symmetries, which commute with Poincare symmetries apart from quantum gravitational effects, makes the boundaries of MEs natural seats of super-symplectic representations, and since these states are genuine quantum gravitational states defined by statefunctionals in the "world of classical worlds", they are expected to be crucial for understanding higher level consciousness.

MEs induce supra currents in superconducting magnetic circuits by magnetic induction mechanism, serve as Josephson junctions between magnetic flux tubes, and induce magnetic quantum phase transitions. MEs can generate reference waves or their phase conjugates (time reversals) acting on lower level MEs serving as dynamical holograms. The induced coherent light pattern would act as a control command or its time reversed version. Conjugate reference waves could provide an extremely simple basic mechanism of healing by time reversal allowing the living matter to fight against second law. MEs could read DNA strand to the light-like vacuum current by drifting along it and thus code DNA strand/conjugate strand to a hologram or its phase conjugate in turn acting as a control command or its time reversal. Thus living matter could be regarded as a symbiosis in which MEs control superconducting magnetic flux tubes controlling ordinary matter at atomic space-time sheets via many-sheeted ionic flow equilibrium. DNA would represent the ROM of this system.

7.1.7 MEs And The Notion Of Conscious Hologram

The notion of conscious hologram is the last step in the development of ideas related to bioholograms. The basic challenge is to generalize the notion of the ordinary hologram to that of a *conscious* hologram, about which bio-holograms would be examples. The notion of quantum gravitational hologram is defined at the level of geometric, purely physical existence whereas conscious holograms exist at the level of subjective existence defined by the sequence of quantum jumps and giving rise to the self hierarchy. Of course, these two notions of hologram must be closely related.

The notion of conscious hologram combines the saint and sinner aspects of consciousness to single concept: macrotemporal quantum coherence due to the generation of bound state entanglement and giving rise to co-operation on one hand, and the dissipative self-organization giving rise to Darwinian selection and competition on the other hand.

In nutshell, the notion of conscious hologram follows from the topological field quantization. Classical fields and matter form a Feynman diagram like structure consisting of lines representing matter (say charged particles) and bosons (say photons). The matter lines are replaced by space-time sheets representing matter (elementary particles, atoms, molecules,...), and virtual bosons are replaced by topological light rays ("massless extremals", MEs). Also magnetic flux tubes appear and together with MEs they serve as correlates for bound state quantum entanglement.

The classical fields associated with MEs interfere only at the nodes, where they meet, and one has a hologram like structure with nodes interpreted as the points of a hologram. Thus one avoids the loss of information caused by the interference of all signals everywhere. This aspect is crucial for understanding the role of em fields in living matter and brain. The MEs corresponding to "real photons" are like laser beams entering the hologram and possibly reflected from it. What is new that the nodes can be connected by "virtual photon" MEs also analogous to laser beams. Hence also "self-holograms" with no laser beam from external world are possible (brain without sensory input).

The hologram has a fractal structure: there are space-time sheets at space-time sheets and high frequency MEs propagating effectively as massless particles inside low frequency MEs serving as quantum entangling bridges of even astrophysical length. The particle like high frequency MEs induce "bridges" between magnetic flux tubes and atomic space-time sheets at the receiving end. This makes possible the leakage of supra currents from magnetic flux tubes to atomic space-time sheets analogous to the exposure of film producing hologram. The leakage induces dissipation, self-organization, and primitive metabolism as a cyclic flow of ionic currents between the two space-time sheets, and thus a Darwinian selection of the self-organization patterns results. Under certain conditions the leakage followed by dropping back to the larger space-time sheet can also give rise to a many-sheeted laser. The low frequency MEs are responsible for the bound state entanglement, macroscopic quantum coherence and co-operation whereas high frequency MEs are responsible for self-organization and competion.

The 3-D vision associated with ordinary holograms generalizes to stereo consciousness resulting in the fusion of mental images associated with the points of conscious hologram [K19].

7.1.8 Negative Energy MEs And Bio-Control

Negative energy MEs correspond to space-time sheets with a reversed time orientation. These MEs serve as correlates for bound state entanglement. Low frequency negative energy MEs can contain inside them high frequency MEs propagating along them like negative energy particles. The possibility to quantum jump to a higher energy state by generating negative energy ME gives rise to the pay now-let others pay mechanism of metabolism. This quantum credit card mechanism makes the functioning of the living system extremely flexible. The fact that ELF MEs play an important role in living matter forces to consider the possibility of remote metabolism and the transfer of metabolic energy even in the length scale of Earth (7.8 Hz frequency corresponds to Earth's circumference). The small energy dissipation related to "our" consciousness could perhaps help to solve "brain's energy crisis" [J10] raised by the puzzling observation that the human brain plus body as a whole does not use more energy than smaller brained mammals with a similar body size.

Negative energy MEs are optimal for the realization of intentions. First p-adic ME transformed to a negative energy ME is generated and serves as a geometric correlate of intention. Then quantum jumps of a real system to a higher energy state occurs and in this quantum jumps p-adic ME is transformed to a negative energy ME to take care of the conservation laws.

Right and left brain hemispheres could have different arrows of the geometric time at appropriate p-adic time scales. For instance, negative energy MEs would make possible quantum communications to the direction of the geometric past. The model of non-episodal memory call would involve quantum communication of the question to the geometric past (time-like entanglement and sharing of mental images), and a classical (dissipative) communication of the answer to the geometric future. Negative-positive energy dichotomy could be be realized in an extremely wide range of time scales and to explain, besides the basic mechanism of long term memory, also precisely targeted realization of intentions, sensory-motor dichotomy, and biocycles as dissipation-healing cycles.

Quantum criticality is the basic characteristic of TGD Universe and quantum critical superconductors provide an excellent test bed to develop the ideas related to quantum criticality into a more concrete form. The hypothesis that Planck constants in CD (causal diamond defined as the intersection of the future and past directed light-cones of M^4) and CP_2 degrees of freedom are dynamical possessing quantized spectrum given as integer multiples of minimum value of Planck constant [K40, K38] adds further content to the notion of quantum criticality.

After several alternatives I ended with the conjecture that the value of $\hbar$ is in the general case given by $\hbar = n \times \hbar_0$. Integer n characterizes a sub-algebra of super-symplectic algebra or related algebra with conformal structure characterized by the property that conformal weights are n-multiples of those of the full algebra. The sub-algebra is isomorphic with the full algebra so that a fractal hierarchy of sub-algebras is obtained. One obtains an infinite hierarchy of conformal gauge symmetry breaking hierarchies defined by the sequences of integers n_i dividing n_{i+1}.

The identification in terms of hierarchies of inclusions of hyper-finite factors of type II_1 is natural. Also the interpretation in terms of finite measurement resolution makes sense. As n increases the sub-algebra acting as conformal gauge symmetries is reduced so that some gauge degrees of freedom are transformed to physical ones. The transitions increasing n occur spontaneously since criticality is reduced. A good metaphor for TGD Universe is as a hill at the top of a hill at the top.... In biology this interpretation is especially interesting since living systems can be seen as systems doing their best to stay at criticality using metabolic energy feed as a tool to achieve this. Ironically, the increase of $\hbar$ would mean increase of measurement resolution and evolution!

The only coupling constant of the theory is Kähler coupling constant $\alpha_K = g_K^2/4\pi\hbar$, which appears in the definition of the Kähler function K characterizing the geometry of the configuration space of 3-surfaces (the "world of classical worlds"). The exponent of K defines vacuum functional analogous to the exponent of Hamiltonian in thermodynamics. The allowed value of $\alpha_K = g_K^2/4\pi\hbar$ should be analogous to critical temperature and determined by quantum criticality requirement. There are two possible interpretations for the hierarchy of Planck constants.

1. The actual value of $\hbar$ is always its standard value and value of $\alpha_K = g_K 2/4\pi\hbar$ is always its maximal value $\alpha_K(n = 1$ but there are n space-time sheets contributing the same value of Kähler action effectively scaling up the value of $\hbar_0$ to $n\hbar_0$ scaling down the value of $\alpha_K(1)$ to $\alpha_K(1)/n$. The n sheets would belong to n different conformal gauge equivalence classes of space-time surfaces connecting fixed 3-surfaces at opposite boundaries of CD. This interpretation is analogous to the introduction of the singular covering space of embedding space.

   One can of course ask whether all values $0 < m \leq n$ for the number of "actualized" sheets are possible. A possible interpretation would be in terms of charge fractionization.

2. One could also speak of genuine hierarchy of Planck constants $\hbar = n\hbar_0$ predicting a genuine hierarchy of Kähler coupling strengths $\alpha_K(n) = \alpha_K(n = 1)/n$. In thermodynamical analogy zero temperature is an accumulation of critical temperatures behaving like $1/n$. Intriguingly, in p-adic thermodynamics p-adic temperature is quantized for purely number theoretical reasons as $1/n$ multiples of the maximal p-adic temperature. Note that Kähler function is the analog of free energy. In this interpretation the n sheets are identified.

Phases with different values n behave like dark matter with respect to each other in the sense that they do not have direct interactions except at criticality for the phase transition changing the value of n to its multiple or divisor. In large $\hbar(CD)$ phases various quantum time and length scales are scaled up which means macroscopic and macro-temporal quantum coherence.

Number theoretic complexity argument favors the hypothesis that the integers n corresponding to Fermat polygons constructible using only ruler and compass and given as products $n_F = 2^k \prod_s F_s$, where $F_s = 2^{2^s} + 1$ are distinct Fermat primes, might be favored. The reason would be that quantum phase $q = exp(i\pi/n)$ is in this case expressible using only iterated square root operation by starting from rationals. The known Fermat primes correspond to $s = 0, 1, 2, 3, 4$ so that the hypothesis is very strong and predicts that p-adic length scales have satellite length scales given as multiples of n_F of fundamental p-adic length scale.

Contrary to the original hypothesis inspired by the requirement that gravitational coupling is renormalization group invariant, α_K does not seem to depend on p-adic prime whereas gravitational constant is proportional to L_p^2. The situation is saved by the assumption that gravitons correspond to the largest non-super-astrophysical Mersenne prime M_{127} so that gravitational coupling is effectively RG invariant in p-adic coupling constant evolution [L42].

$\hbar(CD)$ appears in the commutation and anti-commutation relations of various superconformal algebras. Kähler function codes for radiative corrections to the classical action, which makes possible to consider the possibility that higher order radiative corrections to functional integral vanish as one might expect at quantum criticality. For a given p-adic length scale space-time sheets with all allowed values of Planck constants are possible. Hence the spectrum of quantum critical fluctuations could in the ideal case correspond to the spectrum of Planck constants coding for the scaled up values of Compton lengths and other quantal lengths and times. If so, large $\hbar$ phases could be crucial for understanding of quantum critical superconductors, in particular high T_c superconductors.

A further great idea is that the transition to large $\hbar$ phase occurs when perturbation theory based on the expansion in terms of gauge coupling constant ceases to converge: Mother Nature would take care of the problems of theoretician. The transition to large $\hbar$ phase obviously reduces gauge coupling strength α so that higher orders in perturbation theory are reduced whereas the lowest order "classical" predictions remain unchanged. A possible quantitative formulation of the criterion is that maximal 2-particle gauge interaction strength parameterized as $Q_1Q_2\alpha$ satisfies the condition $Q_1Q_2\alpha \simeq 1$.

TGD thus predicts an infinite hierarchy of phases behaving like dark or partially dark matter with respect to the ordinary matter and each other [**?**] and the value of $\hbar$ is only one characterizer of these phases. These phases, especially so large $\hbar$ phase, seem to be essential for the understanding of even ordinary hadronic, nuclear and condensed matter physics [**?**, K97, K38]. This strengthens the motivations for finding whether dark matter might be involved with quantum critical superconductivity.

Cusp catastrophe serves as a metaphor for criticality. In the case of high T_c superconductivity temperature and doping are control variables and the tip of cusp is at maximum value of T_c. Critical region correspond to the cusp catastrophe. Quantum criticality suggests the generalization of the cusp to a fractal cusp. Inside the critical lines of cusp there are further cusps which corresponds to higher levels in the hierarchy of dark matters labeled by increasing values of $\hbar$ and they correspond to a hierarchy of subtle quantum coherent dark matter phases in increasing length scales. The proposed model for high T_c super-conductivity involves only single value of Planck constant but it might be that the full description involves very many values of them.

MEs and dark matter hierarchy

MEs can be regarded as space-time correlates for a hierarchy of particles characterized by different values of Planck constant and the de-coherence phase transition would naturally correspond to the decay of MEs to smaller space-time sheets. Single sheeted MEs correspond to fermions and their super partners and topologically condensed CP_2 type vacuum extremals representing particles involve only single wormhole throat carrying the quantum numbers. Double sheeted MEs connected by wormhole contacts correspond to bosons and their super-partners with the throats of wormhole contacts carrying the quantum numbers. The two sheets have opposite arrow of time and signs of energies.

The ordinary laser light cannot be regarded as a large $\hbar$ phase, which de-coheres to ordinary photons before the interaction with ordinary matter. Very general consistency arguments lead to the working hypothesis that dark matter and dark MEs correspond to λ^k-fold ($k > 0$) coverings of CD (causal diamond) locally ($\hbar(k) = \lambda^k\hbar_0$, $\lambda = 2^{11}$) whereas ordinary laser light would correspond to $k = 0$.

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` [L13].

7.2 Massless Extremals

The so called massless extremals are very general solution of field equations associated with the minimization of Kähler action parameterized by several arbitrary functions. The characteristic feature of the massless extremals is the presence of light-like currents generating coherent states of photons and gravitons. These features suggest that massless extremals might have important role in bio-systems.

7.2.1 Massless Extremals As General Solutions Of Field Equations

Let $k = (k^0, k^3, 0, 0)$ be a light like vector of M^4 and $u = u(m^1, m^2)$ arbitrary function of the Minkowski coordinates m^1 and m^2 in the plane orthogonal to the direction of the 3-vector $(k^3, 0, 0)$ associated with k. The surfaces defined by the map

$$s^k = f^k(k \cdot m, u) \ , \tag{7.2.1}$$

where f^k and u are arbitrary functions define massless extremals. They describe the propagation of massless fields in the direction of k: the fields are periodic with a period $\lambda = 2\pi/k$ so that only k and its integer multiples are possible wave vectors. The polarization associated with various induced gauge fields depends on the position in (m^1, m^2)-plane and is in the direction of the gradient of u. Field equations involve tensor contractions of the energy momentum tensor and gauge current but these are proportional to kk and k respectively and vanish by the light-likeness of k. Linear superposition holds true only in a restricted sense since both the propagation direction and the polarization direction in each $(m^1, m^2) = const$ plane is fixed.

What is remarkable that these solutions are not solutions of the ordinary Maxwell equations in vacuum: Kähler current density J_K is in general non-vanishing(!) and proportional to the light like four-momentum k. As a consequence, also a light-like electromagnetic current is in general (but not necessarily) present. The interpretation of the em current J as charged elementary particle current is impossible and the correct interpretation as a vacuum current associated with the induced gauge fields. The finite length of the microtubule plus the requirement that the total vacuum charge vanishes, implies that the Fourier decompositions of the massless fields contain only integer multiples of the basic four-momentum k. The direct detection of the light-like vacuum current inside a microtubule would provide strong support for TGD.

The physical importance of these extremals is suggested by the fact they are in certain sense elementary particle like objects: in fact, the original interpretation was as a model for the exterior space-time of a topologically condensed massless particle. The solution set is also very general involving several arbitrary functions. Although the minimization of the Kähler action favors the formation of Kähler electric fields, massless extremals might well appear as space-time sheets of the effective space-time. These space-time sheets should not contain ordinary charges since their presence implies a transition to the Maxwell phase described in an excellent approximation by the ordinary Maxwell electrodynamics.

Rather remarkably, massless extremals are also solutions of the field equations associated with the low energy effective action. This holds true in the absence of the topologically condensed matter, phenomenologically described using external currents. For instance, the term

$$(T^{\alpha\beta}_{\#} - \frac{1}{16\pi G}G^{\alpha\beta})D_\beta \partial_\alpha h^k \ ,$$

where # refers to the topologically condensed matter, reduces to

$$\frac{1}{16\pi G}G^{\alpha\beta}D_\beta \partial_\alpha h^k \ ,$$

and vanishes identically because Einstein tensor is light like so that contraction with the second fundamental form vanishes. The vanishing of these terms in presence of matter is not possible since the gauge currents and energy momentum tensor associated with the topologically condensed matter are not light-like. Thus massless extremals correspond to vacuum space-time sheets with respect to the ordinary matter. Massless extremals can however interact with the ordinary matter via # contacts.

The fact that vacuum em current and vacuum Einstein tensor do not in general vanish, implies that massless extremals serve as sources of coherent photons and gravitons. It is not very economical to maintain BE condensates all the time. In "dormant" states microtubules could correspond to ME: s with vanishing em fields but non-vanishing Z^0 fields or even vacuum extremals of the effective action with one-dimensional CP_2 projection and having vanishing classical gauge fields. Massless extremals can also reduce to vacuum extremals of the Kähler action in the case that the CP_2 projection is, in general two-dimensional, Legendre manifold of CP_2. Also in this case massless extremals are however non-vacuum extremals of the effective action.

7.2.2 About The Electro-Weak And Color Fields Associated With Massless Extremals

Space-time sheets carrying em fields carry usually also Z^0 and W fields and it is not possible to speak about em or Z^0 type MEs. It is however possible to speak about neutral and W MEs. The CP_2 projection of ME is 2-dimensional and in a special case it reduces to a geodesic sphere. There are two kinds of geodesic spheres in CP_2.

1. For space-time sheets for which CP_2 projection is $r = \infty$ homologically non-trivial geodesic sphere of CP_2 one has

$$\gamma = (\frac{3}{4} - \frac{sin^2(\theta_W)}{2})Z^0 \simeq \frac{5Z^0}{8} \quad .$$

   The induced W fields vanish in this case and they vanish also for all geodesic sphere obtained by $SU(3)$ rotation.

2. For homologically trivial geodesic sphere a standard representative is obtained by using for the phase angles of standard complex CP_2 coordinates constant values. In this case induced em, Z^0, and Kähler fields vanish but induced W fields are non-vanishing. This holds also for surfaces obtained by color rotation. Hence one can say that for non-vacuum extremals with 2-D CP_2 projection color rotations and weak symmetries commute.

The MEs corresponding to these two geodesic spheres could be called neutral and W MEs and they carry color fields for which the color group $SU(3)$ reduces to some of its $U(1)$ subgroups. Quite generally, the holonomy algebra of color group is Abelian since the induced color field is of the form $g^A_{\alpha\beta} \propto H^A J_{\alpha\beta}$, where H^A denotes color Hamiltonian.

Neutral MEs are excellent candidates for mediating EEG type communications from the biological body to the magnetic body whereas charge entanglement induced by W MEs would be ideal for the realization of motor actions of the magnetic body by generating first superposition of exotically ionized states of atomic nuclei entangling magnetic and biological body [K37]. State function reduction would lead to an exotically ionized state accompanied by dark plasma oscillation pattern. By Faraday law this pattern would induce electric fields at the space-time sheets containing ordinary matter which in turn would generate ohmic currents leading to various physiological effects.

MEs are excellent candidates for the space-time correlates of laser beams. Dark matter hierarchy implies that also MEs can be classified by the level of the dark matter hierarchy involved. A very general argument leads to the conclusion that dark space-time sheets, in particular MEs, at the k^{th} level of the dark matter hierarchy correspond to space-time sheets defining λ^k-fold coverings of M^4 (recall that one has $\hbar(k) = \lambda^k \hbar_0$ and $\lambda \simeq 2^{11}$) [K118, K37]. $k = 0$ MEs would correspond to the ordinary laser light.

7.2.3 How Massless Extremals Generate Coherent States Of Photons?

ME: s can be in "dormant" or active state according to whether the em current associated with the ME is vanishing or not. In active state ME: s generate Bose Einstein condensate type state for ordinary photons. This means in TGD context the emission of (topological) vapor phase photons (CP_2 type extremals), which can condense on other condensate levels. ME: s generate gravitonic BE condensate and the possible biological role of this condensate will be discussed later.

Assuming that the coupling of quantized photon field to the massless extremal is given by regarding the massless extremal as a classical background field one obtains QED with a light like source J^{α}:

$$\begin{aligned} D_{\beta}F^{\alpha\beta} &= eJ^{\alpha} \ , \\ J^{\alpha} &= Jk^{\alpha} \ . \end{aligned} \tag{7.2.2}$$

The system is equivalent with an infinite number of harmonic oscillators each driven by a harmonic external force and a basic exercise in the quantum mechanics shows that the solutions of the field equations give the new oscillator operators as sums of free oscillator operators plus c-number term, which is essentially the Fourier component of the light like current in the direction of the polarization.

In the limit that ME has infinite duration and is a cylindrical structure of finite length L (that is microtubule) one has for $J \propto sin(k_z(t-z))$

$$\begin{aligned} a^{\dagger}(p) &\rightarrow a^{\dagger}(p) + g(p) \ , \\ g(p) &= \sum_n \delta(p^0, k_n^0)K(p,k_n)J(k_n^z, p_T) \ , \\ K(p,k) &= \epsilon(p)\cdot k\frac{1}{i(p_z-k_z)}(exp(ip_zL)-1) \ , \\ k_n &= nk_0 = \frac{n2\pi}{L}(1,1,0,0) \ . \end{aligned} \tag{7.2.3}$$

Here p denotes the momentum of the photon and k the 4-momentum associated with the Fourier component of a light-like current. $\epsilon(p)$ denotes the polarization of the photon. $J(k_n^z, p_T)$ is essentially the 3-dimensional Fourier transform of the scalar function J. The infrared behavior of $J(k_z, p_T)$ as a function of the transversal momentum p_T can be deduced from the fact that the transverse dimension of the microtubule is small (about 25 nm) as compared to $1/p_T$ so that the Fourier component is in good approximation independent of p_T.

For the frequencies present in the Fourier decomposition of the massless extremal, the ordinary oscillator vacuum is transformed to a coherent state in the corresponding Fourier mode of the quantized photon field. The essential point is that the wave vectors of the radiation field and massless extremal are nonorthogonal. The radiation pattern resembles the ordinary antenna pattern associated with an oscillating current $J(t) = exp(i\omega t)$ in that the intensity of radiation vanishes at angles $\theta = \pi/2$ and $\theta = 0$. For $J \propto sin(k_z(z-t))$ $|K|^2$ has maxima for $\theta = 48.6$ degrees and 131.4 degrees. For an ordinary dipole with $J = sin(\omega t)$, $\omega = 2\pi/L$ the radiation pattern is concentrated at angles $\theta \geq 40$ degrees with maximum and 69.3 degrees and 110.7 degrees.

A more complicated situation corresponds to a group of several massless extremals (say microtubules). If massless extremals are parallel and have same length the previous expression generalizes with superposition of terms

$$g(p) \rightarrow \sum_n exp(i\phi_n)exp(ip_zz_n)exp(ip_T\cdot x_T)g_n(p) \ . \tag{7.2.4}$$

The phase ϕ_n is the phase difference between n: th light like current with respect to some reference current. If the positions of microtubules and/or phases of the individual light like currents are suitably chosen then various terms interfere constructively and macroscopic quantum coherence is obtained at resonant frequencies. Suffice it so say that the needed timing is extremely accurate: less than 10^{-12} seconds! Since p_z is small rather larger transversal distances are allowed by the requirement of constructive interference. In a more general situation also the orientations of microtubules can vary in certain limits. Note that light-like energy momentum generates also gravitonic BE condensates at preferred frequencies.

7.2.4 Massless Extremal Is Accompanied By A Bose-Einstein Condensate Of Parallel Photons

The interaction Lagrangian describing the interaction of photon field with the light-like vacuum current does not couple to the photons collinear with the vacuum current (light-like wave vector has vanishing length squared). Therefore the ground states of the system are degenerate since one can add to any coherent state generated by the vacuum current any number of photons collinear with the vacuum current and topologically condensed inside the massless extremal. This means Bose-Einstein condensation in collinear degrees of freedom.

Collinear Bose-Einstein condensates of photons are crucial for the model of the quantum correlates of the sensory qualia. Sensory quale is characterized partially by the BE condensate of photons associated with the massless extremal parallel to the axon. The existence of the BE condensate makes possible induced emission. For instance, Josephson currents generate photons with frequencies which are multiples of the Josephson frequency. If the potential difference in Josephson junction equals to a multiple of the cyclotron frequency of some super conducting ion, the current flows resonantly in the sense that Josephson current serves as a harmonic perturbation generating quantum jumps and gives rise to a large dissipative current and also quantum jumps in either super conductor. Since the emission rate for photons by the current is proportional to N^2, where N is the number of photons already in the state, the presence of the BE condensate of photons with this frequency amplifies the emission rate. This kind of resonance mechanism is assumed in the model of sensory experience since it elegantly explains why given neuron corresponds to single quale. Since the potential difference over the Josephson junction can correspond to only single cyclotron frequency, the dominance of single quale is unavoidable even when all macroscopic quantum phases are present.

The existing BE condensate increases the probability of topological condensation of coherent photons generated by other massless extremals to the massless extremal. This mechanism could provide inter-neuronal communication mechanism and realize the metaphor about brain as a society of neutrons, the notion of neuronal window idea and also give a more precise content to the music metaphor. In particular, neurons far away from each other could communicate using wavelengths in a narrow wave length range by this mechanism.

The wave vectors of the photons are multiples of $k = \pi/L$. This means that the length of the massless extremal correlates with the maximal allowed wavelength. For ELF photons associated with EEG frequencies of order 10 Hz the length of massless extremal is of order Earth's circumference. This suggests that more general massless extremals with a topology of torus instead of linear topology could characterize the topological field quanta of ELF fields. It is however impossible to say, whether the field equations allow more general solutions resembling massless extremals.

7.2.5 MEs and apparent breaking of Uncertainty Principle

There is a popular article in Science alert (see `http://tinyurl.com/ybm9gcvu`) about finding that light can be squeezed to much smaller volume than the wave length in dimensions transversal to the wave-length by using single-sheeted graphene. The original article by David Alcaraz Aronzo *et al* is published in Science [D26] (see `http://tinyurl.com/ya8u54ax`). A naïve application of Uncertainty Principle suggests that this is impossible since this would mean a very large expectation value of momentum squared in transverse momentum degrees of freedom.

The finding is interesting from the point of view of classical limit of TGD. So called massless extremals (MEs) or topological light rays [K16, K11, K70] are extremely general solutions of field equations (practically independently of the details of the action principle: it is enough that it is general coordinate invariant). The counterparts of MEs are not possible in Maxwellian electrodynamics but TGD allows them because of the extreme non-linearity of the underlying geometric variational principle for which the topological pair of Maxwell's equations involving no currents is identically satisfied.

What MEs are?

MEs are 4- surfaces describing the propagation of massless topological field quanta of induced classical fields characterized by light-like propagation direction and polarization orthogonal to it.

Classical 4-momentum is light-like. The propagation occurs with a maximal signal velocity, and there is no dispersion so that the pulse shape is preserved. If there are several pulses they must propagate in the same direction. The propagation of a laser beam in waveguide serves as an analogy. MEs are be ideal for targeted communications and MEs associaged with magnetic flux tubes and carrying dark photons assignable with wormohole contacts play a key role in TGD inspired quantum biology. A possible interpretation is as space-time correlates Bose-Einstein condensate of photons. Photons themselves would correspond to wormhole contacts (actually pairs of them) connecting ME to another space-time sheet, which could be magnetic flux tube or even ME.

MEs have finite size scale in directions orthogonal to the direction of propagation and MEs can be arbitrary thin. I do not see any reason why they could not be thinner than wavelength. The graphene seems to provide a situation in which classical modelling by MEs makes sense.

The QFT limit is obtained from many-sheeted space-time by replacing many-sheeted structure with a region of Minkowski space made slightly curved. Gauge potentials and gravitational fields are sums of the corresponding induced fields at space-time sheets so that the effects of these fields on a test particle sum up although fields themselves are at different space-time sheets. The linear superposition of Maxwell's theory is replaced with a set theoretic union of the space-time sheets in M$^4_2$.$Theeffectsofthefieldsofspace-timesheetsonthetestparticlesumupjustlikeinsuperpositionoffieldsinMaxwell's$

For instance, this allows a situation in which one has two MEs describing propagation of signals in opposite directions as far effects on test particles are considered. This gives rise to standing waves not possible in TGD as single sheeted extremals. Lorentz transforms give analogs of em signals propagating with arbitrary velocity smaller than light velocity. Even field patterns for which the QFT limit corresponds to vanishing fields because the effects on test particles are trivial are possible: both sheets however carry non-vanishing fields with non-vanishing energy-momentum density.

Why the apparent breaking of Uncertainty Principle?

Why the apparent breaking of Uncertainty Principle is then possible in TGD? The point is that in TGD particles do not correspond to wavefunctions in a fixed space-time - this is true only at quantum field theory limit of TGD. Instead, they correspond to wave functions in what I call "world of classical worlds" (WCW). 3-space as "world" is in TGD replaced with 3-D surface defining the "world". In zero energy ontology (ZEO) one can identify space-time surfaces as preferred extremals of an action, which in a well-defined sense generalizes the Maxwell action for a point like charged particle. Thanks to holography the space-time surface is characterized by 2 3-surfaces at its opposite ends -initial and final 3-surfaces - located at the opposite boundaries of causal diamond (CD), whose M^4 projection is intersection of future and past directed light-cones and would look like diamond if it were 2-D. The world as 3-D surface or equivalently 4-D surface is the quantum dynamical object and space-time ceases to be a passive arena of dynamics. Uncertainty Principle holds true for wave functions in WCW rather than for induced fields at space-time surfaces. Therefore the apparent breaking of Uncertainty Principle is possible.

7.3 Microtubules As Quantum Antennae

7.3.1 Linear Structures As Quantum Antennae

The many-sheeted space-time concept of TGD indeed allows almost vacuum space-time sheets and these space-time sheets might be crucial for the understanding of the bio-systems. For instance, the weak interaction of these space-time sheets with the ordinary space-time sheets containing matter could provide representations of the external world in the physical properties of the almost vacuum space-time sheets. In particular, mind-like space-time sheets having finite time duration could generate coherent light and coherent light might make communication possible between mind-like space-time sheets and realize the idea of neuronal window discussed briefly in introduction [K26]. The mind-like space-time sheets associated with various linear structures are especially natural candidates for massless extremals serving as quantum antennae. Bio-systems are full of linear structures and the mind-like space-time sheets associated with microtubules, DNA and protein molecules are the most obvious candidates for quantum antennae.

7.3.2 Are Microtubules Accompanied By Massless Extremals?

The interior of the microtubule is by its cylindrical symmetry an ideal place for ME: s whereas the axonal cell membranes must correspond to "Maxwell phase", where ordinary Maxwell equations are satisfied in a good approximation but also a separate space-time sheet is possible candidate for a massless extremal. The function $u(x, y)$ appearing in the general solution is most naturally $u(x, y) = \sqrt{x^2 + y^2}$ for microtubules implying radial polarization. The explanation of the macroscopic quantum coherence in the brain would provide crucial support for the TGD based world picture since massless sources and vacuum currents are not possible in the ordinary QED.

There is analogy with the super radiance phenomenon [J39]: in this case however the photons radiated by the microtubule waveguide have momenta parallel to the microtubule so that the mechanism leading to the formation of the macroscopic BE condensate remains to be understood. The theories associating coherent photons with the microtubules typically assume that the coherent photons reside inside the microtubules: this leads to problems since Uncertainty Principle; the direct study of Maxwell equations also suggest that photons should have very large transversal momenta corresponding to the transversal dimension of the microtubule of order 10^{-8} meters. In TGD this difficulty is avoided since only the *sources* of the coherent photons are restricted into the interior of microtubules whereas the photons can exists in vapor phase and condense on various space-time sheets of the topological condensate.

The necessary condition for the formation of the coherent states in the presence of the matter is that ME condensate level does not contain ordinary gauge charges. If ME corresponds to a larger space-time sheet "below" the space-time sheet containing the ordered water, this requires that the gauge charges of the condensed matter do not flow to the interior of the ME space-time sheet. This is achieved if the condensed particles combine by flux tubes together to form a net like structure so that gauge fluxes can run along the flux tubes to the boundary of the ME region, where they can flow down to the ME condensate level. Ordered water is a good candidate for this join along boundaries/flux tube condensate. Microtubules are known to be surrounded by ordered water and also the interior contains ordered water. The axial electric polarization of the microtubular surface suggests that there is a longitudinal electric gauge flux at the condensate level of the ordered water running to/from the ME condensate level at the ends of the microtubule. The wave lengths appearing in the Fourier expansion of J are of form L/n, L being microtubule length.

In the active mode microtubule acts as a quantum antenna creating quantum coherent light unlike the ordinary antenna, which creates incoherent light. Also waveguide mode is possible for the topologically condensed photons but antenna mode is crucial for the generation of the macroscopic coherent states. The following argument suggests that he dielectric properties of the microtubule surface can change the antenna pattern somewhat. The dipoles of the microtubule are known to be parallel to the axis of the microtubule. The interaction energy of a dipole p with the radiation field is proportional to the quantity $p \cdot E = pEcos(\theta)$ so that the effect of the dielectric is largest, when the wave vector of the photon is orthogonal to the axis of the microtubule. As a consequence, the dipole pattern should concentrate in the forward direction.

The em current in the interior transforms ordinary QED vacuum to a coherent state in the resonating Fourier modes of the photon field. In ME mode the resonance energies come as multiples of $E_0 = 2\pi/L$ and wavelength L/n, where L is the length of the microtubule whereas in VE mode the spectrum is continuous. Biophotons [I84] with energy of order one eV might be regarded as evidence for BE states associated with the shortest microtubules (such as centriole and basal bodies). The average length of the neuronal microtubules is about 10^{-5} m and corresponding IR radiation is more energetic than thermal IR radiation with a wavelength of order 10^{-4} m.

In the ME mode the resonances at energies $E_n = nE_0$, $E_0 = 2\pi/L$, provide ideal communication channels. Microtubules with different lengths provide independent communication channels so that very effective communication in principle becomes possible. This process could orchestrate axonal microtubules as well as the microtubules belonging to different neurons to form a larger macroscopic quantum state. An optimal performance is obtained if the microtubules belonging to same group are parallel and their lengths are quantized with a common multiple. The microtubules of the neighboring neurons indeed tend to be parallel. Axonal microbutules are also parallel whereas the microtubules inside the ordinary cells are in radial configurations. The grey matter in brain has a columnar structure so that axonal microtubules tend to be in the direction of the columns: this should favor the formation of a quantum resonance between different microtubules.

Furthermore, the model of [I27], described in Tuscon II, for the microtubule interactions predicts that the microtubules of even far away neurons are parallel. The average length of the neuronal microtubules is about 10^{-5} m and it is known that the response of 3T3 cells to weak IR radiation is maximum at this wavelength. Neurons could be able to tune their microtubules to the desired infrared stations by controlling their orientation and length. The upper bound about 10^{-4} meters for the length of the axonal microtubules can be understood: for the longer microtubules the thermal IR radiation becomes important and makes communication impossible. In long axons this problem is avoided by joining shorter microtubules in series via Microtubule Associated Proteins (MAPs).

Since the time scale for the change of the tubulin polarization is of order 10^{-10} seconds and the period of the IR radiation is of order 10^{-13} seconds, amplitude modulated IR transmissions are possible. The mechanism of the amplitude modulation could be simply a change of the microtubule interior gauge field from active to dormant ME mode. Amplitude becomes vanishing if this field becomes ordinary sourcefree em field or Z^0 field. IR transmissions could be based on some kind of binary code resembling genetic code. There is indeed concrete proposal of Koruga for this code motivated by the geometric structure of the microtubule surface. [I34] , [J28]. One possibility is that the propagating modes of dipole and conformational oscillations perform elementary AM modulations. These modes could correspond to elementary language expressions at the level of the microtubules.

Microtubules can also absorb photons coming from an external source at resonance energies. If Bose-Einstein condensate of N photons in some mode is present, the absorption probability is amplified roughly by the factor N^2 as shown in appendix. This suggests that microtubules containing BE condensate of photons in some mode are able to “see” in some elementary sense. Of course, receiving antenna containing the BE condensate need not be microtubule. Centrioles (T shaped pair of microtubules inside animal cells) could provide cell with infrared eye and there is experimental evidence for this in the case of monocellular organisms [I61]. Also the radial microtubules could have elementary sense of vision. Note that all eukaryotic cells have radial structure of microtubules in their cytosceleton.

7.3.3 How Macroscopic Quantum Coherence Is Generated?

The big problem is the creation of constructive interference between the coherent states associated with different microtubules. The problem looks exceedingly difficult: microtubules should be able to tune up the frequency and phase associated with light like current inside microtubule with those of other microtubules contributing to the coherent state. Frequency tuning, or equivalently length tuning, involves time scales smaller than 10^{-13} seconds in case of infrared light associated with longest microtubules. The simplest solution to come into mind is that there exist some pacemaker keeping the microtubules in rhythm. One can imagine several mechanisms important for the tuning, each involving the special properties of the TGD space-time crucially.

Topological field quantization

TGD space-time surface decomposes into regions characterized by vacuum quantum numbers, which are frequencies and integers related to the time and angle dependences of the phase angles associated with the two complex CP_2 coordinates. Typically one has $\Phi = \omega t + Fourier\ expansion$ so that space-time surface vibrates with frequency ω. This vibration is an ideal candidate for a pacemaker for the physical systems inside a given space-time region. In fact, the vacuum quantum numbers characterize partially also the order parameter of a super conductor. Vacuum frequencies could also be special frequencies for the Maxwell fields.

The increased understanding about topological field quanta as classical and quantum coherence regions of em field is consistent with and generalizes this view. When topological field quanta are joined by join along boundaries bond generated in quantum jump they fuse to form a larger region of classical and quantum coherence. This suggests a general mechanism for how various axons/microtubules can generate phase coherent em fields. What is needed is that there is larger space-time sheet connected by flux tubes to the massless extremals associated with various axons/microtubules. This larger space-time sheet is most naturally the geometrical counterpart of higher level self so that consciousness is what creates synchrony rather than vice versa!

A further important aspect in the generation of synchrony is self-organization. The subsystems of self quantum self-organize and end up to asymptotic self-organization patterns selected by dissipation. These patterns are simple and typically involve spatially repeating patterns and synchronous oscillations (Benard flow is simple example of this). It is consciousness which implies synchrony and coherence whereas in standard approaches to quantum consciousness synchrony and coherence are believed to be prerequisites for consciousness.

Phase locking for the system of Josephson junctions

Japanese physicist Yoshiki Kuramato from the University of Kioto has shown that the solutions of the differential equations describing Josephson junctions tend to a state in which there is single collective oscillation frequency. A.T. Winfree from the University of Arizona has shown that a phase transition to single collective oscillation frequency analogous to the freezing of liquid occurs in this kind of system.

The solutions of the differential equations describing Josephson junctions model quantum self-organization and synchronization can be interpreted as an instance of the selection of asymptotic self-organization patterns selected by dissipation and occurring always in quantum self-organization. Of course, the quantum jumps can occur only provided the system of Josephson junction belongs to a system having self so that consciousness is again prerequisite for synchrony rather than vice versa! In any case, the fact that entire brain is hierarchy of space-time sheets such that the space-time sheets at various levels are connected by Josephson junctions makes this result rather encouraging.

Gap junctions and MAPs

As noticed, the formation of the join along bonds is the basic prerequisite for the formation of the macroscopic quantum systems. The so called gap junctions can be regarded as flux tubes between the cell membranes (understood as 3-surfaces in TGD picture) of the neighboring cells. They could have a key role in synchronous firing of neuron groups. Gap junctions could also force the vacuum quantum numbers of the neighboring cell membranes to be identical as well as provide the bridges for the propagation of the Maxwell type fields between neighboring cells. It is known that the coherently firing neuron groups in brain possibly responsible for the generation of sensory experience are gap junction connected. It is not however obvious whether gap junctions have anything to do with the synchronizing of the vacuum currents: the difference between the time scales involved is indeed huge. Also Microtubule Associated Proteins could act as join along boundaries bonds/flux tubes guaranteeing quantum coherence between microtubules inside same cell.

7.3.4 Are Nerve Pulse Patterns Coded Into Vacuum Currents And Coherent Light?

It has turned out that TGD based model for memetic code leads to the same interpretation of nerve pulse patterns as suggested by neuroscience. Nerve pulse/no nerve pulse corresponds to true/false Boolean statement or 1/0 value of binary digit. Fundamental coding of nerve pulse patterns is the coding into temporal sequences of cognitive neutrino pairs associated with cell membrane such that the spin of the cognitive antineurino codes for true/false (1/0). Of course, bits could code also for binary digits in the binary expansion and code for the intensity of the primitive sensory experience associated with the neuron. It is natural to ask whether nerve pulse patterns could be also coded to some other representations. Light-like currents are indeed optimal in this respect.

The dependence of the light-like current on the longitudinal coordinate of massless extremal is arbitrary and therefore light-like current provides ideal tool of classical communication of information with light velocity as well as coding of this information to coherent light received by other massless extremals. The first bio-application to come into mind is that the instantaneous nerve pulse patterns propagating along the axon could be coded into the pattern of the vacuum current. The velocity of propagation for the nerve pulse pattern is extremely small as compared to light velocity but this is not a problem if the coding takes place in the region where nerve pulses are generated. What happens is that same temporal pattern of pulses propagates with different velocities. This coding in turn implies coding of nerve pulses to coherent states of photons and in principle the communication of nerve pulse pattern to other neurons.

The relationship between memetic and genetic code is that between two hierarchy levels of a computer program. This suggests that nerve pulse patterns representing memetic codons could serve as transcription factors at gene level. This requires the communication of nerve pulse patterns to nucleus. Even more, communication mechanism must treat different presynaptic inputs as different inputs. Modulation of the vacuum current could make possible communication of the nerve pulse patterns to the cell nucleus along the massless extremals associated with the radial microtubules which in case of neurons have direct contact with the cell membrane. The fact, that some anesthetics seem to affect microtubules and that some brain diseases involve changes of microtubules could also be explained as a breaking of the cell membrane-nucleus communication link. That this kind of communication link might exist is suggested by the fact that ELF em fields have direct efect on genetic expression [J48].

7.4 Masless Extremals And Information Molecules

The notion of information molecule is central for the understanding of biological control. There are however several rarely asked questions related to the notion of information molecule: in particular, the phenomenon of pleiotropy is not easy to understand on basis of pure chemistry [I72]. TGD inspired view about biocontrol and coordination suggests a general answer to these questions and leads to a general model of biological control based on both MEs and information molecules with massless extremals (MEs) serving as actual information carriers and information molecules having a a role analogous to that of computer passwords.

7.4.1 Questions About Information Molecules

Central nervous system (CNS), endocrine system and immune system are three basic systems involved with bio-control and -communication. The work of Candace Pert and other neuroscientists has led to a general notion of information molecule described in popular manner by Candace Pert [J22]. Neural transmitters and modulators associated with CNS are only special cases of information molecules. Also neuropeptides and various hormones are involved. It has become clear that emotions are closely related with the activity of information molecules and that both brain, endocrine system and immune system communicate intensively with each other. One could regard even brain as a big gland. Of course, one could also consider various glands and organs as mini-brains.

The interactions of the information molecules involve the formation of receptor-information molecule complex either at cell surface or in the cell plasma inside cell. Receptor-information molecule complex inside cell can move to genome and induce gene transcription. In case that the complex is formed at the surface of cell, second messenger action is involved. One can also speak about N: th messenger action. There are many poorly understood aspects related to the mechanisms of information molecule action [I72].

1. There are only few second messenger pathways and relatively few receptors but large number of different functions. This phenomenon is known as pleiotropy or multi-functionality. For instance, given second messenger causes different effects depending on the hormone that activated it (the phenomenon is somewhat analogous to the phenomenon in which message can be understood in several ways depending on the state of receiver). At purely chemical level the problem is how second messenger knows what hormone activated it? In steroid action the complex formed by information molecule and receptor in turn activates some gene. Now the question is: How the activated RNA polymerase knows which gene has to be activated? Pleiotropy appears also at level of hormones. Same hormone can have multiple effects and the border between hormone, neuropeptide or even neurotransmitter is unclear. For instance, hormone which by definition transmits long distance communications, can have effects in nearby cells and thus acts like a neuropeptide. How hormone knows what function it must perform? Also drugs and treatments can have different effects and side effects.

2. There is also functional redundancy: the same function is performed by several second messenger molecules. For instance, glucagon, growth hormone, adrenaline and corticosteroids elevate glucose levels. This suggests that there is deeper level of communication involved and that second messenger molecules are more like computer passwords than subprogram calls. Now the question is: What these subprogram calls do correspond physically?

3. Biological functions can be initiated also in non-chemical manner. The phenomena of healing by touch and the effects of meditation and biofeedback are examples of biological self-organization processes are initiated in non-chemical manner. Even other treatments like massage, acupuncture or meditation can decrease or inhibit pain. These observations suggest that chemical level is not the deepest level involved with biological functions and the question is: What is this deeper control level?

Simple lock and key mechanism cannot provide answer to the questions raised above. Rather, computer password might provide better metaphor for the second messenger action whereas receptor-information molecule complex would effectively generate subprogram call perhaps carried by the second messenger molecule or possibly broadcasted. It seems that information molecules act more like signs or symbols rather than being purely chemical agents. These symbols are interpreted by cell level intelligences and the interpretation depends on context.

7.4.2 A Model Of Biological Self-Organization Based On Quantum Antenna Hypothesis

The view that self hierarchy is present already at molecular level and realized in terms of MEs provides rather straightforward interpretation of pleiotropy and redundancy. The phenomenon of pleiotropy suggests there is non-chemical communication between receptor-peptide complex and cell nucleus. The most natural TGD inspired candidate for the communication is wake-up of genome sub-self by general wake-up mechanism in which classical em field associated with ME induces quantum jumps leading to quantum phase transition which could correspond to the transcription process. The almost-determinism of the transcription process would be due to the Darwinian selection caused by dissipative effects.

These considerations suggest that information molecule-receptor complex could generate ME carrying classical gauge fields and vacuum current. Vacuum current is excellent candidate for coding the information and can lead to a generation of coherent light.

1. The first possibility is broadcasting. The ME associated with information molecule receptor-complex acts as active quantum antenna and activated structure, say genome, serves as a passive quantum antenna receiving the coherent light. Classical fields and/or coherent light would induce quantum jumps serving as seeds of quantum phase transitions leading to a wake-up of conscious and self-organizing sub-self inside receiver.

2. Alternatively, second messenger molecule could carry the information carrying ME with itself as a genuine message inducing the self-organization process in, say, genome.

A natural hypothesis is that the states of the exotic Super Virasoro representations define the macroscopic quantum phases in question: the reason is that these representations are present in all length scales. The information molecule-receptor pair corresponds to a definite frequency, or more generally, combination of frequencies, coding the corresponding function. For instance, genes might be coded to harmonics of Super Virasoro frequencies associated with various p-adic length scales. All information molecule-receptor combinations initiate some function determined by these frequencies and pleiotropy emerges as a basic prediction of the model. Second messenger pathway is like a password to computer, universal key, together with the frequency or even entire ME specifying the function in question: this initiates the desired self-organization process waking-up proper sub-self.

These ideas suggest the following general framework for understanding biological self-organization.

1. Biological programs consist of self-organization patterns generated by classical gauge fields associated with MEs at specific resonance frequencies inducing quantum jumps leading to quantum phase transitions. These resonance frequencies serve as names of the genetic subprograms. Messenger molecules in turn serve in the role of computer passwords.

2. Self-organization processes are associated with MEs and generated by special frequencies, which could be harmonics of the fundamental frequencies associated with various exotic Super Virasoro representations. For instance, combinations of harmonics of various Super Virasoro transition frequencies could define "name of gene". The fact that these frequencies are constants of Nature means that the model is immediately testable. Of course, also other transition frequencies, in particular, magnetic and Z^0 magnetic transition frequencies, could be important.

3. The ability of a biological system to act effectively like a deterministic computer is due to the Darwinian selection of the asymptotic patterns of self-organization caused by dissipation in systems which are fed by energy.

4. The four-dimensionality of this self-organization process is also important element. The frequency of ME defines time scale $T = 1/f$ which defines the duration of biological chronon. With this interval of geometric time entire 4-dimensional space-time surface changes in self-organization process.

7.5 Evidence For Quantum Antenna Hypothesis

In the following some evidence for quantum MEs and quantum antenna hypothesis is discussed. It must be emphasized that there is also other evidence discussed in other chapters of the book (for instance, see the chapters [K41, K82, K85].

7.5.1 TGD Inspired Model For Sonoluminescence

Sonoluminescence [D18] is a peculiar phenomenon, which might provide an application for the hydrodynamical hierarchy. The radiation pressure of a resonant sound field in a liquid can trap a small gas bubble at a velocity node. At a sufficiently high sound intensity the pulsations of the bubble are large enough to prevent its contents from dissolving in the surrounding liquid. For an air bubble in water, a still further increase in intensity causes the phenomenon of sonoluminecence above certain threshold for the sound intensity. What happens is that the minimum and maximum radii of the bubble decrease at the threshold and picosecond flash of broad band light extending well into ultraviolet is emitted. Rather remarkably, the emitted frequencies are emitted simultaneously during very short time shorter than 50 picoseconds, which suggests that the mechanism involves formation of coherent states of photons. The transition is very sensitive to external parameters such as temperature and sound field amplitude. In the following only the rough hydrodynamical characteristics of the phenomenon are considered from the point of view of p-adic length scale hypothesis. Also an attempt to understand the mechanism behind quantum coherence in terms of light-like vacuum currents associated with massless extremals is made.

Sonoluminescence and hydrodynamic hierarchy

A plausible explanation for the sonoluminescence is in terms of the heating caused by shock waves launched from the boundary of the adiabatically contracting bubble [D18]. The temperature jump across a strong shock is proportional to the square of Mach number and increases with decreasing bubble radius. After the reflection from the mimimum radius $R_s(min)$ the outgoing shock moves into the gas previously heated by the incoming shock and the increase of the temperature after focusing is approximately given by $T/T_0 = M^4$, where M is Mach number at focusing and $T_0 \sim 300\ K$ is the temperature of the ambient liquid. The observed spectrum of sonoluminescence is explained as a brehmstrahlung radiation emitted by plasma at minimum temperature $T \sim 10^5\ K$.

The model reproduces nicely the time development of the bubble and sonoluminescence spectrum and explains sensitivity to the external parameters [D18]. The problem is to understand how the length scales are generated and explain the jump-wise transition to sonoluminescence and the decrease of the bubble readius at sonoluminescence: ordinary hydrodynamics predicts continuous increase of the bubble radius. The length scales are the ambient radius R_0 (radius of the bubble, when gas is in pressure of 1 atm) and the minimum radius $R_s(min)$ of the shock wave determining the temperature reached in shock wave heating. Zero radius is certainly not reached since since shock front is susceptible to instabilities.

Since p-adic length scale hypothesis introduces a hierarchy of hydrodynamics with each hydrodynamics characterised by a p-adic cutoff length scale there are good hopes of achieving a better understanding of these length scales in TGD. The change in bubble size in turn could be understood as a change in the "primary" condensation level of the bubble.

1. The bubble of air is characterized by its primary condensation level k. The minimum size of the bubble at level k must be larger than the p-adic length scale $L(k)$. This suggests that the transition to photoluminescence corresponds to the change in the primary condensation level of the air bubble. In the absence of photoluminescence the level can be assumed to be $k = 163$ with $L(163) \sim .76\ \mu m$ in accordance with the fact that the minimum bubble radius is above $L(163)$. After the transition the primary condensation level of the air bubble is $k = 157$ with $L(157) \sim .07\ \mu m$. In the transition the minimum radius of the bubble decreases below $L(163)$ but should not decrease below $L(157)$: this hypothesis is consistent with the experimental data [D18].
2. The particles of hydrodynamics at level k have minimum size $L(k_{prev})$. For $k = 163$ one has $k_{prev} = 157$ and for $k = 157$ $k_{prev} = 151$ with $L(151) \sim 11.8\ nm$. It is natural to assume that the minimum size of the particle at level k gives also the minimum radius for the spherical shock wave since hydrodynamic approximation fails below this length scale. This means that the minimum radius of the shock wave decreases from $R_s(min, 163) = L(157)$ to $R_s(min, 157) = L(151)$ in the transition to sonoluminescence. The resulting minimum radius is 11 nm and much smaller than the radius .1 $\mu\ m$ needed to explain the observed radiation if it is emitted by plasma.

A quantitative estimate goes along lines described in [D18].

1. The radius of the spherical shock is given by

$$R_s = At^\alpha \ , \tag{7.5.1}$$

where t is the time to the moment of focusing and α depends on the equation of state (for water one has $\alpha \sim .7$).

2. The collapse rate of the adiabatically compressing bubble obeys

$$\frac{dR}{dt} = c_0\left(\frac{2}{3\gamma}\frac{\rho_0}{\rho}\left(\frac{R_m}{R_0}\right)^3\right)^{1/2} \ , \tag{7.5.2}$$

where c_0 is the sound velocity in gas, γ is the heat capacity ratio and ρ_0/ρ is the ratio of densities of the ambient gas and the liquid.

3. Assuming that the shock is moving with velocity c_0 of sound in gas, when the radius of the bubble is equal to the ambient radius R_0 one obtains from previous equations for the Mach number M and for the radius of the shock wave

$$\begin{aligned} M &= \frac{\frac{dR_s}{dt}}{c_0} = (t_0/t)^{\alpha-1} \ , \\ R_s &= R_0(t/t_0)^\alpha \ , \\ t_0 &= \frac{\alpha R_0}{c_0} \ . \end{aligned} \tag{7.5.3}$$

where t_0 is the time that elapses between the moment, when the bubble radius is R_0 and the instant, when the shock would focus to zero radius in the ideal case. For $R_0 = L(167)$ (order of magnitude is this) and for $R_s(min) = L(151)$ one obtains $R_0/R_s(min) = 256$ and $M \simeq 10.8$ at the minimum shock radius.

4. The increase of the temperature immediately after the focusing is approximately given by

$$\frac{T}{T_0} \simeq M^4 = (\frac{R_0}{R_s})^{\frac{4(1-\alpha)}{\alpha}} \simeq 1.3 \cdot 10^4 \ . \tag{7.5.4}$$

   For $T_0 = 300\ K$ this gives $T \simeq 4 \cdot 10^6\ K$: the temperature is far below the temperature needed for fusion.

   In principle the further increase of the temperature can lead to further transitions. The next transition would correspond to the transition $k = 157 \rightarrow k = 151$ with the minimum size of particle changing as $L(k_{prev}) \rightarrow L(149)$. The next transition corresponds to the transition to $k = 149$ and $L(k_{prev}) \rightarrow L(141)$. The values of the temperatures reached depend on the ratio of the ambient size R_0 of the bubble and the minimum radius of the shock wave. The fact that R_0 is expected to be of the order of $L(k_{next})$ suggests that the temperatures achieved are not sufficiently high for nuclear fusion to take place.

The model of sonoluminescence by Buzzacchi, del Giudice and Preparata

The coherence of the light generated in sonoluminescence looks rather mysterious from the view point of standard physics. There is very interesting paper of Buzzacchi, del Giudice and Preparata about sonoluminescence with title "*Sonoluminescence Unveiled?* " [D18]. The study of this paper revealed that the physical picture behind microtubule as quantum antenna hypothesis leads to a model for sonoluminescence and that sonoluminescence could be interpreted as a direct evidence for light-like vacuum currents generating coherent photons in TGD. Needless to say, vacuum currents are a purely TGD based phenomenon and implied by the induced gauge field concept deriving from the hypothesis that space-time is 4-dimensional surface in certain 8-dimensional space.

The assumptions of the work of Buzzacchi, del Giudice and Preparata [D18] are following.

1. The energy of the coherent radiation created in sonoluminescence results from the latent heat 0.26 eV per molecule for gas to liquid phase transition occurring at the final stage of the bubble collapse. In [D18] the latent heat is used to deduce the width Γ of the energy spectrum of photons.

2. When shock wave is formed during the collapse of bubble (collapse velocity becomes supersonic), a front of layers with distance that between water molecules is formed. The average distance of molecules in tangential direction are much larger but gets smaller during the collapse of bubble. One can say that there is vapor layer looking like water in radial direction but in transversal directions the layer is much less dense. When the radius of the buble reaches certain critical value (so that density is about 1/3 of the density of liquid phase), condensation in the transversal directions to liquid occurs. Note that this means that there is preferred direction suggesting cylindrical symmetry for the condensing regions.

3. The phase transition is assumed to occur in coherent regions with size of order $\lambda \simeq 500$ Angstroms, which is not far from the diameter of microtubules. In these regions there is a coherent plane wave electromagnetic field with frequency $\omega = 2\pi/\lambda$ and the decay of this field produces the highly synchronized light flash of duration of less than 10^{-11} seconds.

4. The physical origin of the coherent regions is somewhat mysterious in standard physics but authors propose that QED is enough to explain the mystery. Authors identify the source of coherent light as resulting from the transitions between two different molecular energy states with energy difference $\Delta E \simeq 12$ eV. One could criticize this assumption as ad hoc. In any case, classical current must be defined as expectation value, which vanishes unless the two energy eigen states get mixed by interactions.

TGD inspired model for sonoluminescence

Consider now the TGD based modification of this model based on the same assumptions 1), 2), 3) about the origin of the coherent light as related to the liquid-gas phase transition but with different identification for the mechanism producing the coherent light. The model is based on the idea that bubble collapse might involve the sequential formation of several new space-time sheets with p-adic primes $p \simeq 2^k$, $k = 163, 157, 151, 149$ characterizing their typical sizes. The importance of the many-sheeted space-time concept was realized already in the previous rough model of the phenomenon just suggesting the identification of the basic scales of the problem in terms of the p-adic length scale hypothesis but involved no model for the generation of coherent light.

a) Light like vacuum currents generate coherent light

What is known is that the light flash emitted is *coherent* light. All frequencies are emitted simultaneously. The temporal widths of various frequencies do not depend on the nature of the gas. Thus the spectrum is certainly not genuine black body spectrum and the production mechanism must involve macroscopic quantum coherence. In TGD there indeed exists a unique mechanism leading to the generation of coherent light and is based on so called "massless extremals" carrying light-like *vacuum currents* generating coherent light in a resonant like manner. Clearly, this mechanism predicts no dependence of the spectrum on the chemical nature of the gas in bubble. Of course, the gas can affect the spectrum by absorbing some frequencies and this indeed seems to occur. It is also known that the presence of noble gases is favorable for sonoluminescence: this is perhaps understandable from the fact that presence of noble gases (no absorption) reduces the effect of other gases by reducing their densities. In TGD inspired theory of bio-systems as macroscopic quantum systems massless extremals correspond to almost empty space-time sheets associated with microtubules and possibly also other linear bio-structures and create coherent photons (perhaps bio-photons of Popp [I84]).

b) Vapor-liquid phase transition in regions of microtubular size occurs

Following [D18], it will be assumed shockwave formation leads to the formation of vapor layers with the mutual distance $a \simeq 3.2$ Angstroms equal to the average distance between liquid molecules and that condensation to liquid occurs when the transversal distance between the molecules of the layer becomes smaller than some critical distance $a < a_T < a_0$, where $a_0 \simeq 3.2 \times 10^{-7}$ meters is the transversal distance of the molecules when shockwave is generated. In the model of [D18] $a_T \simeq \sqrt{3}a$ holds true: in TGD based model p-adic argument gives $a_T = 2a$. In TGD framework the formation of liquid phase is assumed to mean the formation of new cylindrical space-time sheets of size of order 500 Angstroms, when the transversal distance between H_20 molecules becomes critical (3 times the distance in liquid phase). At these space-time sheets water molecules are condensed into liquid phase. The length scale 500 Angstroms is suggested by [D18] and in TGD framework the justification for this length scale is that it corresponds to the diameter of microtubules: these cylindrical structures could serve as templates for the formation of microtubules). Rather flat cylinders with radius equal to height are in question: of course, one can consider also cubic geometry.

c) p-Adic length scale hypothesis

p-Adic length scale hypothesis makes this picture more quantitative. Before the phase transition vapor phase is join along boundaries/flux tube condensate of $k = 151$ space-time sheets glued to $k = 157$ sheets. Note that $L(151) \simeq 10^{-8}$ meters corresponds to the thickness of the cell membrane: now however the sheets are larger having size of order 500 Angstroms. Gas-to liquid phase transition is identified as a phase transition changing the value of the p-adic prime p: most naturally $k = 151 \rightarrow k = 149$. This implies $a_T = 2a_0$ rather than $\sqrt{3}a_0$ as in the model of [D18]. Therefore the critical density is $\rho^* = \rho(liquid)/4$ instead of $\rho(liquid)/3$ of [D18]. Using the relationship

$$a_T(t) = a_0 \frac{R(t)}{R_0} \quad , \tag{7.5.5}$$

where $R_0 \simeq 4.5\mu m$ is the radius of the bubble when contraction velocity becomes supersonic one obtains for the transversal distance a_T^* at criticality:

$$a_T^* \simeq 2a = a_0 R^*/R_0$$

giving $R^* \simeq .9\ \mu m$ to be compared with $R^* \simeq .8\ \mu m$ of [D18].

One can estimate the thickness of the condensing shell from the requirement that the number of molecules in the shell with inner and outer radii R^* and R_0 at time t_0 is same as the number of molecules in the thin liquid shell at time when condensation to liquid has occurred. This gives for the thickness T of the liquid shell

$$T \simeq \frac{R_0^2}{R^{*2}}\frac{a^3}{a_0^3}(1-\frac{R^{*3}}{R_0^3})R_0 \ , \tag{7.5.6}$$

giving $T \simeq 10^{-7}$ meters which is *two* (!) times the size of the coherence domain as suggested by the transversal size of microtubules.

d) Topological details of the phase transition process

Consider next the topological details of the process. The transversal size of $k = 151$ sheets is (most naturally) halved in the phase transition and the flux tubes connecting $k = 151$ sheets to each other are probably split. According to the basic rules of p-adic TGD, space-time sheets with different p-adic prime p can have only wormhole contacts as stable contacts. This means that, for a p-changing phase transition to take place, the bonds connecting $k = 151$ sheets belonging to different sides of the shock front must be split, probably immediately after the formation of the shock wave. The inward flow of the newly formed $k = 149$ sheets slows down whereas the flow of $k = 151$ sheets behind them continues: the molecules condensed on them cannot however follow the flow since they collide with the liquid phase. Therefore these sheets become thus almost vacuum space-time sheets and the $k = 149$ sheets containing liquid phase topologically condense on them. At this stage the vacuum currents are generated on these almost empty $k = 151$ sheets.

e) Generation of coherent light

In the last stage of the process vacuum currents are generated on the almost empty $k = 151$ sheets and they generate the coherent light giving rise to the flash. The experience with microtubules as quantum antennae hypothesis suggests that massless extremals carrying classical light-like vacuum currents flowing in radial direction are in question. The vacuum current, possible *only* in TGD context, generates coherent photons and the flux of coherent photons from the system creates the coherent flash of photons. The frequency spectrum for the current associated with the massless extremals comes in multiples of the basic frequency π/L, L being the length of the cylinder, which is roughly equal to the thickness of H_2O layer condensing to liquid (this length is expected to have some distribution). The dependence of the vacuum current on transversal and longitudinal coordinate, which is not specified by the field equations for the vacuum extremals, in principle determines the energy spectrum. The model for the sonoluminescence should be able to predict the form of the vacuum current but this requires a model for the coupling between the parameters of the vacuum current and ordinary matter.

The model of [D18] suggests that only the lowest frequency $\omega_0 = 2\pi/L$ is effectively present. The spectrum of [D18] is of form

$$\begin{aligned}
\frac{1}{V}\frac{dE}{d\omega} &= \frac{3\omega_0^3}{16\pi^3}|c_1|^2|F(\omega)|^2\frac{\omega^2}{(\omega-\omega_0)^2+\Gamma^2/4} \ , \\
|c_1|^2 &\simeq 1.8 \ , \\
F(\omega) &= exp(-1.4\frac{\omega^2}{\omega_0^2}) \ .
\end{aligned} \tag{7.5.7}$$

It is of considerable interest to verify that a spectrum, which is product of a form factor and resonance factor, results also now. The presence of the form factor $F(\omega)$ reflects the dependence of the vacuum current on transversal coordinate, which for cylindrical geometry is radial coordinate.

The dependence on the transversal coordinate is left completely open by the field equations and the unknown coupling of the vacuum current with matter should determine it. The resonance factor has a purely kinematical origin: the energy spectrum for photons has form $1/(\omega-\omega_0)^2$ resulting from the fact that matrix element for photon emission involves the overlap integral $\int exp[i(\omega-\omega_0)t]dt$ over a finite time-interval. One must take dissipation into account so that the real spectrum is proportional to $1/\left[(\omega-\omega_0)^2+\Gamma^2/4\right]$. The resonance width is of order $\Gamma \simeq 18$ eV and in [D18] it is determined by the requirement that total energy output equal to the latent heat .28 eV per molecule.

The order of magnitude for the duration of the flash can be estimated from the radial contraction velocity $dR/dt(t_0) \simeq 1.5 \times 10^3 m/s = 10^{-5}c/2$ of the bubble at the moment t_0 when the phase transition begins (according to [D18]) and from the length $l \leq 500$ Angstroms, which the empty $k = 151$ sheets must travel before $k = 149$ sheets can condense on them. This gives the estimate $t(flash) \simeq 3 \times 10^{-11}$ seconds which is less than the experimental upper bound $t(flash) < 5 \times 10^{-11}$ seconds,

To summarize: sonoluminescence could provide a direct verification for the concept of massless extremal and light-like vacuum currents. Gas-liquid phase transitions could quite generally involve the formation of massless extremals. Perhaps massless extremals of microtubular size are always present in liquid phase but carry very weak vacuum currents and bio-systems are perhaps able to amplify them. One could perhaps understand all phase transitions as formation of new space-time sheets involving p-changing phase transition.

7.5.2 Stirred And Shaken

Japanese chemist Kazamuri Dozen and his colleagues have observed mysterious splitting of water into hydrogen and oxygen at room temperature using a simple catalyst (copper oxide in powder form) and by stirring the liquid [I75, I75]. The quicker the container is stirred the more hydrogen and oxygen are produced. Usually the dissociation occurs at temperature of about 3000 C and is driven by light: the photon density of thermal radiation has maximum at $E \sim 4T$ giving the estimate $E \sim 1.32$ eV: which gives an estimate for the energy of O–H bond possibly lowered by the presence of a catalyst. Notice that the photons in question correspond to visible light. Domen believes that direct transformation of the kinetic energy of the liquid motion to chemical energy must take place: standard wisdom allows only the transformation *kinetic energy → thermal energy → chemical energy.* There is no idea about the underlying mechanism. According to [I75, I75] already 1980 analogous direct transformation of acoustic energy to chemical energy was discovered and gave rise to the field of sonochemistry. An attractive possibility is that liquid motion somehow generates coherent light which in turn drives the reaction. Similar mechanism might be at work in sonochemistry. Since sonoluminescence involves the transformation of mechanical energy into coherent light, quantum antenna hypothesis is an obvious guide line in the attempt to identify the mechanism.

The simplest TGD based mechanism explaining the anomalous splitting of hydrogen is following.

1. Stirring creates linear cylindrical vortex like structures, which are accompanied by space-time sheets carrying light like vacuum currents. The splitting to oxygen and hydrogen is driven by the coherent light emitted by the vacuum currents associated with cylindrical structures of length L. The energies for the photons of the coherent light come as multiples of $E_0 = \pi/L$ (or of $E_1 = 2\pi/L$ if periodic boundary conditions are assumed). For $E = E_0 \sim 1.32$ eV this gives the estimate $L \sim .47 \cdot 10^{-6}$ meters. This length scale is not too far from the p-adic length scale $L(163) \sim .64 \cdot 10^{-6}$ meters assuming that $L(151)$ corresponds to cell membrane thickness $L(151) \simeq 10^{-8}$ meters.

2. The rotational motion creates classical Z^0 magnetic fields realized as Z^0 magnetic flux tubes and a natural expectation is that these flux tubes are accompanied by cylindrical space-time sheets carrying light like vacuum currents. Since quarks feed their Z^0 gauge fluxes to the space-time sheets having typically twice the cell size, the naïve expectation for the length of the cylindrical structures in question would be of order $L(169) \sim 5 \cdot 10^{-6}$ meters, which is however almost by one order of magnitude too large. This of course does not exclude the possibility that Z^0 magnetic flux tubes are in question. The generation of Z^0 magnetic flux

tubes was suggested already many years ago to explain the observed loss of the super fluidity at much smaller critical rotational velocity than predicted by standard physics [K51].

3. A possible function of the catalyst powder is to lower the O–H bonding energy, so that it is nearer to the energy of the photons of the coherent light.

What is interesting from the point of view of consciousness theorizing is that in gel-phase vigorous streaming of intracellular liquid occurs. Furthermore, the coherent photons causing dissociation would correspond to visible light. Therefore one can wonder whether the generation of light-like vacuum current emitting coherent bio-photons [I84] could be one function of the streaming. A possible test for this hypothesis is to look for an additional sink of metabolic energy inside cell.

7.5.3 Evidence For Quantum Antenna Hypothesis In Living Systems

It is known that some monocellulars possess elementary vision based on the microtubules [I61]. The emergence of the multicellulars during the Cambrian explosion was preceded by the appearance of the microtubules. If the emergence of the microtubules meant the emergence of the visual consciousness in the length scale of the cell, then the formation of the multicellulars as cell societies can be understood as a natural consequence. The length distribution of the microtubules in the rods and cones of the eye is concentrated in the region of the visible wavelengths. The coherent light in question could be identifiable as bio-photons of Popp [I84].

A further piece of evidence comes from the work of Callahan about the sense of smell of insects [I86]. Many insects, such as moths and ants, are known to be attracted by light, say candles and electric lamps and Callahan took as his challenge to understand what is involved. Callahan discovered that insect's olfaction is not based on chemistry but to a maser like emission of infrared light generated by various molecules such as pheromones, scent molecules and many other biomolecules. Thus insects would see rather than chemically perceive the sources of the infrared light. The sensillae of the insects serve as receiving antennas and amplify the incoming infrared radiation. Callahan also observed that the oscillation of insect antennae induce maser like emission from scent/etc. molecules by creating an oscillating emf. Thus sensory experiencing seems to involve active participation from the part of insect. The results of Callahan suggest that coherent light could be important also in our neuronal sensory experiencing.

Quite remarkably, pheromones are known to mediate sexual and social signals also in case of many mammals. For instance, certain chemical messages from female mouse can make male mouse to mate immediately while certain chemical messages from other males make him aggressive. Many mammals, for instance rodents, are known to possess vomeronasal organs, small cigar like sacks containing neurons and having length of order few millimeters [J1], giving rise to an accessory olfactory system, which is known to have much more primitive structure and to work in different way than the ordinary olfactory system. It is also known that this systems bypasses cerebral cortex in rodents. There is evidence that even humans have the ability to sniff certain chemicals mediating social and sexual signals without being aware of it and there is already now an entire perfume industry based on this evidence. The chemicals giving rise to sexual attraction are probably pheromones. The fact that pheromones mediate sexual signals in case of both insects and mammals, is hardly an accident and suggests that the sensory mechanism must be the same and be based on the infrared emissions by pheromones. If the response is at neuronal level and if the cortex is not involved, one could understand why these messages are not experienced consciously. One could test this hypothesis by finding whether coherent infrared radiation at frequencies emitted by pheromones can affect the behavior of higher mammals including humans.

There is a further peculiar co-incidence: the cascade of transduction events occurring in the absorption of photon in retina is repeated in a remarkably similar way in olfactory receptor cells, which respond to odors whereas the receptor cells that respond to sound use a very different system [J1]. Could this mean that also the experience of odor primarily involves the detection of (also) infrared light so that humans would not basically differ from insects or that olfactory system has evolved from the receptor neurons originally sensing infrared light? This would conform with the idea that the Kähler field generated in ear corresponds to classical Z^0 field, which does not generate coherent photons but couples with neutrinos. One must however notice that the resemblances between visual and linguistic imagery suggest that some part of ear generates cognitive representation based on coherent light and experienced by the secondary sensory organs in the thalamus.

In CASYS'2000 conference Peter Marcer reviewed the work done by him in collaboration with Russian group [I45] providing experimental evidence for the hypothesis that DNA acts as receiving and sending quantum antenna. What was observed that irradiation of DNA with visible laser light induced emission of coherent light with both visible and radio frequencies. The emitted radiation was also modulated in time scale of about .01 seconds. The modulation could be due to propagation of soliton sequences propagating along Josephson junction formed by the strands of DNA or due to non-propagating spatially constant Josephson current: both cases are mathematically equivalent with gravitational pendulum

7.5.4 Biefeld-Brown Effect

Biefeld-Brown effect was invented as early as 1926 and is one of the oldest poorly understood electromagnetic anomalies [H4, H12, H19]. The basic experiments are following.

1. Capacitor is balanced on beam balance and then charged. If the positive pole of the capacitor points upwards, the condenser moves up. If it points down the condenser moves down.

2. Capacitor is placed in free suspension such that the normal orthogonal to the plane of capacitor plates is horizontal and then charged. Capacitor is found to exhibit a horizontal thrust in the direction of the positive plate.

   Thus it seems that when capacitor is provided with large charge, a force acting on capacitor in direction normal to the plane of the capacitor is observed. The motion takes place to the direction of the positively charged plate. The larger the surface area A of the capacitor, the shorter the distance d between the plates, the larger the mass M between the capacitor plates, the higher the relative dielectric constant ϵ of the dielectric, the larger the voltage V used, the larger is the size the effect. This behavior can be understood if the size of the effect is proportional to the total electric energy $E_e = \epsilon \frac{AV^2}{d}$ between capacitor plates. It is difficult to understand this effect in standard physics framework.

Consider first experiment 1) in which the normal of the capacitor plane is in vertical direction. This experiment could be understood in the general conceptual framework described in the chapter [K110]. Capacitor generates some net gravitational flux. This flux is in general fed to several space-time sheets, although most of it goes to the "standard" sheet at which the gravitational field of Earth resides. One could understand the result of the experiment a) in terms of a redistribution of these gravitational fluxes. When the positive plate points upwards/downwards the flux $\phi_{gr}(Earth)$ fed to the "standard" space-time sheet is reduced/increased. Therefore the effective weight of the capacitor decreases/increases. The dependence of $\phi_{gr}(Earth)$ on the relative orientation of the gravitational field and electric field is not surprising from TGD point of view since classical gravitational and electric fields are very closely related in TGD framework. If classical Z^0 electric force contributes to the effective gravitational force significantly, then similar mechanism in case of Z^0 electric flux could contribute significantly to the change of the effective weight of the capacitor.

It seems that this mechanism cannot explain the result of the second experiment in which capacitor moves to horizontal direction. Rather it seems that two effects must be involved. there must be some mechanism giving for the capacitor momentum in the direction of the electric field. The TGD based general mechanism of energy production relying on the generation of space-time sheets with negative time orientation and carrying negative energies could explain this aspect of Biefeld-Brown effect.

1. Suppose that the charging of capacitor involves generation of space-time sheet with negative time orientation. The energy density associated with classical fields at this space-time sheet is negative. Energy conservation requires that capacitor receives compensating energy which in case of Biefeld-Brown effect is partially realized as kinetic energy associated with center of mass motion.

2. The classical gauge fields associated with the negative energy space-time sheet can carry also momentum and compensating momentum must be developed at the space-time sheet of the capacitor. Therefore condenser is forced to move. The momentum density of em field is proportional to the cross product $E \times B$ of the electric and magnetic fields. This momentum density gives rise to a net field momentum in the direction orthogonal to the plane of condenser plates if E and B are in directions parallel to the plates. This resembles somewhat the situation encountered in the case of Hall effect.

A working hypothesis worth of studying is that the negative energy space-time sheet associated with the capacitor corresponds to a massless extremal with E and B fields propagating from positive to negative plate (field momentum is in this direction).

1. Momentum conservation implies that the space-time sheet of the capacitor generates opposite momentum so that capacitor must move in the direction normal to the plane of the plates. What remains to be understood why the direction of motion is towards the positively charged plate. The light-likeness of 4-momentum gain together with the presence of Fourier components with single direction of wave vector means that momentum gain per energy gain is maximal. Therefore generation of negative energy "massless extremals" is optimal mechanism of propulsion. Massless extremals can have also net angular momentum since polarized Fourier components carry spin. Therefore capacitor can gain internal angular momentum in some form.

2. Assuming that the entire momentum of the classical field on negative energy space-time sheet is compensated by the momentum gain of capacitor, one obtains for the total energy gain

$$E_t = M\beta \ ,$$

where M is total mass of the capacitor and β is its velocity (the units $\hbar = 1$, $c = 1$ are used). This means quite large energy gain. For instance, for $M = .01$ kg and $\beta = 10^{-12}$, one has $E_t \sim 10^2$ Joule. The energy ΔE, which is not realized as kinetic energy, is given by

$$\Delta E = M\beta(1 - \frac{\beta}{2}) \ .$$

Obviously, only a small fraction of the energy is realized as kinetic energy of the capacitor.

The ratio of the energy to thermal energy is given by

$$\frac{E_t}{E_{th}} \sim A\frac{m_p\beta}{T} \ ,$$

where A denotes atomic number. This ratio is much smaller than one for $\beta \ll T/Am_p$. In room temperature this gives $\beta \ll 10^{-11}/A$. An estimate for the magnitude of the electric field is obtained from $E_t = P$. Expressing everything in terms of integrals of energy and momentum densities, one obtains $EB \sim \rho\beta$. Since $E = B$ holds true for massless extremals, one has $B \sim \sqrt{\rho\beta}$. In condensed matter densities one has $\rho \sim Am_p/a^3$, where a is Bohr radius. This gives $B \sim \sqrt{10^5 A\beta}/a^2$. B is roughly about one $\sqrt{A}$ Tesla for $\beta \sim 10^{-12}$. Very strong electric and magnetic fields are clearly involved.

The proposed mechanism might also make possible to understand how living systems are able to generate coherent motions.

1. The ability of bio-systems (70 per cent of water!) to generate coherent motions is complete mystery from the point of view of standard physics describing bio-system as a soup of randomly moving atoms and molecules. The generation of massless extremals provides an optimal mechanism for coherent motion. Negative energies are not absolutely essential for generating coherent motions. However, if massless extremals have positive energies, the efficiency of energy usage is however very low, approximately $\beta/2$, where β is the velocity generated: something like 10^{-8} if velocity is of order one meter per second. It could quite

well be that massless extremal is created only for the period of time that motion lasts: this in accordance with the idea that classical counterparts of virtual particles are in question. Since the surplus energy generated on the material space-time sheet is partially dissipated during this time interval, this mechanism requires that metabolism feeds energy to the system to compensate this loss. Thus there is no contradiction with the general wisdom about the necessity of metabolic energy feed.

2. Brown observed that capacitors had definite effects on plants and animals. This is not surprising if TGD picture about bio-systems is correct. Coherent light is generated and this coherent light can affect the communications of neuronal society.

3. If bio-systems can generate negative energy massless extremals, a very efficient generation of metabolic energy from vacuum becomes possible. There is a lot of anecdotal evidence about the ability of yogis and mystics to survive without eating [J65]. The explanation often proposed by yogis themselves [J65] is that the energy of light replaces the usual sources of the metabolic energy. Standard science sceptics of course "know" and ridicule all this but, against the background of new physics predicted by TGD, I cannot avoid asking myself whether there might be some seed of truth behind these claims.

7.6 Appendix: A Model For The Topological Condensation Of Coherent Vapor Phase Photons

In ordinary QED classical gauge fields can have only ordinary charged particles as their sources. In TGD genuine vacuum currents are possible. The coupling of the quantum field to the classical em field with a non-vanishing vacuum source implies the generation of a coherent state of photons such that each Fourier component present in the classical gauge current gives rise to an eigen state of the corresponding photonic annihilation operator. In case of light-like vacuum currents allowed by TGD, the coherent state is generated in resonant-like manner so that light-like vacuum current acts as an ideal quantum antenna.

If one introduces a second space-time sheet, which contains BE condensate of photons for some modes of the photon field, a stimulated topological condensation of both coherent vapor phase photons and transfer of coherent condensed photons from other space-time sheets to this space-time sheet occurs. This effect makes possible the action of the second space-time sheet as an optimal receiving antenna. In the following calculation the consideration is restricted to the stimulated condensation of vapor phase photons.

In biological context microtubules could server both as senders and receivers of coherent photons. According to the proposed identification of coherent photons as the quantum correlate of vision, the microtubules contain BE condensate of photons in some some modes would have the ability to see in some primitive manner.

7.6.1 The Action

The simplest model for the situation is based on Maxwell action for electromagnetic field regarded as an induced field obtained from superposition of the classical emf in CP_2 degrees of freedom and second quantized free emf in $M^4_+ \times CP_2$ having only M^4 components and depending on M^4_+ coordinates only and having decomposition into vapor phase and condensate parts ($\hbar = 1$ and $c = 1$ will defined the units used in the following).

$$\begin{aligned}
F_{\mu\nu} &= F_{\mu\nu}(cl) + F_{\mu\nu}(qu) \ , \\
F_{\mu\nu}(cl) &= F_{kl}(cl)\partial_\mu s^k \partial_\nu s^l \ , \\
F_{\mu\nu}(qu) &= F_{kl}(qu)\partial_\mu m^k \partial_\nu m^l \ , \\
F_{kl}(qu) &= \partial_l A_k(qu) - \partial_k A_l(qu) \ , \\
A_k(qu) &= A_k(qu,v) + A_k(qu,c) \ .
\end{aligned} \tag{7.6.1}$$

$F_{kl}(qu)$ satisfies empty space Maxwell equations. m^k and s^k refer to M^4_+ and CP_2 coordinates and v and c refer to vapor phase and condensate.

Maxwell action density can be transformed to a sum of a total divergence reducing to mere boundary term, to be neglected, plus free part and two interaction terms in the following manner:

$$
\begin{aligned}
\frac{L}{\sqrt{g}} &= \sum_i L(free,i) + L_1(int) + L_2(int) \ , \\
L(free,i) &= \frac{1}{4}F_{\mu\nu}(qu,i)F^{\mu\nu}(qu,i) \ , \ i = c,v \ . \\
L_1(int) &= \frac{1}{2}j^{\mu}(cl)\sum_i A_{\mu}(qu,i) \ , \\
L_2(int) &= \frac{1}{2}\sum_i J^{\mu}(qu,i)A_{mu}(cl) \ , \\
J^{\mu}(qu,i) &= F^{\mu}_{k}(i)M^{k\nu}_{\nu} + F_k{}^{\nu}(i)M^{k\mu}_{\nu} \ , \ i = c,v \\
M^{k}_{\alpha\beta} &= D_{\beta}\partial_{\alpha}m^k \ .
\end{aligned}
\tag{7.6.2}
$$

$L(free,i)$ denotes the free action for the classical emf and vapor phase and condensed quantum emfs and defines photon propagators. Standard propagator is obtained, when Minkowski coordinates are used for space-time surface.

$L_1(int)$ corresponds to the action of the vapor phase and condensed quantum emf with the vacuum current and leads to generation of coherent state of photons both in vapor phase and condensate.

$L_2(int)$ is non-vanishing only, when the M^4_+ part of the second fundamental form $M^k_{\alpha\beta}$ for 4-surface is non-vanishing: in this case the em current associated with $A_{mu}(qu)$ is non-vanishing despite the fact that it vanishes for $A_k(qu)$! This term describes the external curvature of the 4-surface as opposed to the internal curvature described by the curvature tensor. In general case, the external curvature can be large even when the gravitational field vanishes. It must be however emphasized that this term is proportional to the metric of CP_2 and, in case of the massless extremals, this term is significant only if the dependence of CP_2 coordinates on the transversal coordinates of M^4_+ is strong: this in turn requires huge value for the light-like Einstein tensor. This term will be neglected in the sequel.

The representation

$$
\begin{aligned}
&A_+(k,\lambda) = \sqrt{\tfrac{2\pi}{\omega_k}}a^{\dagger}(k,\lambda) \ , \\
&\left[a(k_1,\lambda_1),a^{\dagger}(k_2,\lambda_2)\right] = \delta^3(k_1-k_2)\delta_{\lambda_1,\lambda_2} \ ,
\end{aligned}
\tag{7.6.3}
$$

for which the density of states factor for photon states is $dN = d^3k$, will be used in the sequel.

7.6.2 Coherent State Is Generated In Resonant-Like Manner For Light-Like Vacuum Currents

The presence of the vacuum current leads to the generation of coherent state of photons both in vapor phase and condensate. Coherent states states are eigen states of the photonic annihilation operators and in the estimates for the rate of topological condensation, one in a good approximation one can replace $A_{\mu}(qu,i)$, $i = cond, vap$, with the classical photon field $A_{\mu}(coh,i)$ having classical vacuum current as its source and serving as order parameters for the coherent state. The Fourier component of a vector potential describing the eigenvalue of the annihilation operator part of the photon field is for given momentum k and polarization direction λ given by

$$
\begin{aligned}
A^{\mu}(coh,v|\lambda,k) &= \sum_n c(k,k_n)\frac{\lambda_{\mu}J^{\mu}(k_n)\lambda^{\mu}}{k_n^2} \ , \\
exp(-ik\cdot m) &= \sum_n c(k,k_n)exp(-ik_n\cdot m) \ .
\end{aligned}
\tag{7.6.4}
$$

$c(k,k_n)$ is the Fourier component of the plane wave $exp(-ik\cdot m)$ expressed using discrete plane wave basis for the space-time sheet containing the vacuum current. m denotes Minkowski coordinates.

If the classical vacuum current is associated with a "massless extremal", em current is light-like and this implies resonance for those frequencies for which photon wave vector corresponds to the wave vectors appearing in the vacuum current. The resonance is smoothed out by the finite spatial size of the space-time sheet containing the light-like vacuum current. At the limit of an infinitely large spatial size for the space-time sheet, one obtains infinitely large amplitude since one has $k_n^2 = k^2 = 0$ at this limit.

7.6.3 Stimulated Topological Condensation

The presence of the coherent state of photons implies the possibility of the topological condensation of photons. If the device contains $N(k,\lambda)$ photons in the state (k,λ), stimulated topological condensation, completely analogous to the stimulated emission, occurs and the condensation rate is proportional to $(N(k,\lambda)+1)^2$.

Assume that there exists a coherent state generated by quantum antenna of possibly astrophysical dimension and associate label "1" with this space-time sheet. Assume also a second space-time sheet and associate with it label "2". In the lowest order the matrix element for the topological condensation of single photon can be obtained as the matrix element of the creation operator part of the interaction term of the action

$$\begin{array}{l} iS_+ = \frac{i}{2}\int_{V_2} dV_2 j^\mu_\perp(coh,1)A_{\mu,+}(cond,2) \\ = \frac{i}{2}\sum_{\lambda_2}\int d^3k_2 X(k_2,\lambda_2)a^\dagger(k_2,\lambda_2) \ , \\ X(k_2,\lambda_2) = \sqrt{\frac{2\pi}{\omega_{k_2}}}\sum_{\lambda_1}\int d^3k_1 Y(k_1,\lambda_1,k_2,\lambda_2) \ , \\ Y(k_1,\lambda_1,k_2,\lambda_2) = j(coh,1|k_1,\lambda_1)c(k_1,k_2)e_{\lambda_1}\cdot e_{\lambda_2} \ , \\ c(k_1,k_2) = \int_{V_2} dV_2 exp\left[i(k_1-k_2)\cdot m\right] \ , \end{array} \tag{7.6.5}$$

between the initial and final states. $j^\mu(coh,1)$ is just the transversal part of the classical vacuum current creating the coherent state. The latter expression is obtained by using Fourier expansions for j and A_+ (, which denotes the creation operator part of the free photon field projected to the space-time surface representing the device: Minkowski coordinates are used for both source regions and device).

In case that the region V_1 is box of length L in the direction of the vacuum current, the explicit calculation, writing the light-like vacuum current as $j^\mu = Jp^\mu$, $p^0 = p^z = 1$, leads to the following expression for the Fourier component $j(coh,1|k_1,\lambda_1)$:

$$\begin{array}{l} j(coh,1|k,\omega_k,\lambda) = j^\mu(coh,1|k,\omega_k)e^\lambda_\mu \ , \\ = \sum_n \frac{exp(ik_zL)-1}{ik_z}J(\omega_n,k_T)p\cdot e^\lambda\delta(k^0-\omega_n) \ , \\ \omega_n = \frac{n\pi}{L} \ . \end{array} \tag{7.6.6}$$

Delta-function expresses the fact that only discrete frequencies are allowed for the vacuum current and one can write the condensation amplitude as a sum $iS_+ = i\sum_n iS_{+,n}$ over the allowed frequencies ω_n. k_T refers to the transversal part of the wave vector orthogonal to the light-like vacuum current.

From this expression one can deduce the probability for the topological condensation of photon (k,λ) to a state containing $N(k,\lambda)$ photons as

$$|S(k,\lambda)|^2 = |\sum_n S_{+,n}|^2(N(k,\lambda)+1)^2 \ , \tag{7.6.7}$$

Clearly, $(N(k,\lambda)+1)^2$ factor corresponds to the induced condensation. By a standard trick one can eliminate the square of the delta-function by replacing the condensation probability with condensation rate $R(k,\lambda)$ obtained by dividing condensation probability with $T\to\infty$ eliminating one delta function. Furthermore, one can calculate the transition rate to a set of final states by multiplying the expression thus obtained with the density of states factor $dN = d^3k$, which after the elimination of the second delta function effectively reduces to $\omega_n^2 d\Omega$. In this manner one obtains for the differential condensation rate a a rather neat expression in terms of the vacuum current

$$\begin{array}{l} \frac{dR(k,\lambda,n)}{d\Omega} = \frac{\pi}{2}\omega_n L^2 |M(k,\lambda|^2 (N(k,\lambda)+1)^2 \ , \\ M(k,\lambda) = i\sum_{\lambda_1}\int d^3k_1 J(\omega_n, k_T^1) c(k^1,k) X(k_1,\lambda_1) \ , \\ X(k_1,\lambda_1) = \frac{exp(ik_z^1 L)-1}{ik_z^1 L} p\cdot e_{\lambda_1} e_{\lambda_1}\cdot e_\lambda \ . \end{array} \tag{7.6.8}$$

From this expression it is clear that resonance indeed occurs and at the limit $L \rightarrow \infty$ the rate for condensation diverges as L^2. In this expression the overlap integral $c(k_1, k_2)$ carries information about the geometry of the space-time sheet associated with the "device" whereas $J(\omega_n, k_T)$ characterizes the vacuum current and the remaining factor X is a purely "kinematic" factor.

Chapter 8

Quantum Control and Coordination in Bio-Systems: Part I

8.1 Introduction

The purpose of this and next chapter is to discuss a model of quantum control and coordination at general level and consider also some examples. Before dwelling down to the details, it is useful to briefly describe the basic philosophy in its present form. A more detailed view about about background can be found from the previous chapters [K87, K69, K23].

8.1.1 Quantum Criticality As A Prerequisite For Quantum Control

Hierarchies involve masters and slaves. Master-slave hierarchy, defined in the spirit of Haken's theory of self-organization, is indeed a natural dynamical correlate of the self hierarchy. Quantum control is possible only if the system is initial value sensitive, that is critical. TGD universe is indeed quantum critical: this also predicts the existence of macroscopic quantum phases in all length scales. Quantum criticality implies initial value sensitivity. There is very beautiful connection with information theoretic aspects: quantum critical universe is in a well defined sense the most intelligent and interesting universe that can exist in TGD framework. Quantum criticality fixes the value of the Kähler coupling strength as a parameter analogous to critical temperature and makes TGD a unique theory (as a matter fact, entire hierarchy of values corresponding to p-adic length scale hierarchy appears).

Quantum criticality should have also space-time correlate. The Kähler-Dirac equation allows to reduce the construction of the geometry of the world of classical worlds (WCW) to the fermionic level needed to construct gamma matrices of WCW. The preferred extremals defining the analogs of Bohr orbits must be critical in the sense of having an infinite number of deformations for which the second variation of Kähler action vanishes. The criticality of Kähler action would thus the basic dynamical principle of space-time dynamics. Purely number theoretic conditions in turn lead to the conclusion that space-time surfaces must be associative (co-associative) in the sense that the modified gamma matrices span associative (co-associative) plane at each point of the space-time surface. "Co-" means that the orthogonal complement of this plane is hyper-quaternionic (associative). Whether criticality and associativity (co-associativity) are consistent is not clear.

$1/f$ noise, which seems to be universal phenomenon popping up in all kinds of contexts, provides direct evidence for quantum criticality. The standard explanation as self-organized criticality is subject to severe criticism since criticality by the definition is something unstable. Situation changes if the fundamental constant of Nature is analogous to critical temperature: there exists simply no perturbations external to the entire universe changing the value of a fundamental constant.

Spin glass analogy could be regarded as one aspect of quantum criticality and states the TGD universe can be regarded as quantum spin glass. Quantum spin glass is phenomenologically characterized by its fractal energy landscape containing valleys inside valleys inside valleys giving rise to extremely complicated system. Quantum self-organization can be described as motion in this kind of energy landscape. p-Adicity can be regarded as one aspect of the quantum spin glassiness. Bio-system as a self-organizing quantum critical spin glass together with the notion of many-sheeted space-time provides rather restrictive general guide line for attempts to construct a general theory of bio-control and -coordination.

The understanding of quantum criticality has developed dramatically after writing during period 2014-2015.

1. The physical interpretation for the hierarchy of Planck constants would be in terms of a hierarchy of quantum criticalities concretizing the vision about quantum criticality of TGD Universe. TGD Universe would be like a hill at the top of a hill at .... The larger the Planck constant the larger the size scale of the hill. Criticality involves crucially the notion of conformal gauge symmetry. The conformal symmetries correspond to sub-algebra of the full algebra isomorphic to it acting as gauge symmetries and with conformal weights coming as n-multiples of those for the full symmetry algebra. $h_{eff} = n \times h$ would label the levels of the hierarchy. This hierarchy would correspond directly to the hierarchy of measurement resolutions and to hierarchy of hyperfinite factors of type II_1 (HFFs). Also now one obtains infinite hierarchies of symmetry breakings and the identification with the hierarchies of inclusions of HFFs is compelling. Hence various hierarchies reflect the same underlying phenomenon.

2. The phase transitions reducing criticality would take place spontaneously unlike opposite phase transitions. This vision is especially powerful in biology, where homeostasis could be seen as mechanisms preventing the reduction of criticality but at expense of metabolic energy. The basic goal of living system would be staying at criticality. Eastern philosophies would formulate this fight for staying at criticality using the notions of ego and Karmic cycle. In the phase transition increasing $h_{eff} = n \times h$ part of gauge degrees of freedom assignable to a sub-algebra of the full super-symplectic algebra are transformed to physical ones and this implies better measurement resolution. The new HFF contains the previous one as sub-factor. Evolution understood as increase of h_{eff} forced by Negentropy Maximization Principle as also interpretation improvement of measurement/cognitive resolution.

The most important outcome is certainly the understanding the paradoxical character of life as a fight to stay at criticality while phase transitions increasing Planck constant tend to occur spontaneuosly and increase the negentropic resources of the system.

8.1.2 P-Adic Evolution

Number theoretic entanglement entropies served as the key to a deeper understanding of what distinguishes living matter from dead matter. These entropies can be negative but make sense only if entanglement probabilities are real or algebraic numbers in the extension of p-adic numbers considered. This is implied by number theoretic universality in the intersection of real and p-adic variants of the embedding space which at QFT limit of TGD correspond to discrete points of partonic 2-surfaces carrying elementary particle numbers. Their motion along light-like 3-surfaces gives rise to number theoretic braids [K28].

At configuration space level the intersection of real and p-adic worlds would correspond to a more abstract intersection with the counterpart of rationals identified as light-like 3-surfaces represented by rational functions with rational coefficients identifiable as common to real and p-adic worlds. State function reduction to the intersection of p-adic and real worlds would induce also the rationality (or algebraic number property) of the entanglement probabilities since they must make sense both p-adically and in the real sense. One might say that the enlightment means living in both real and p-adic world simultaneously.

One way to understand the special role of rationals and algebraics relies on the observation that rationals represent islands of order in the sea of chaos defined by reals since their pinary expansion is predictable and analogous to a periodic orbit of a dynamical system whereas for a generic real number there is no way to predict the pinary expansion.

The phase transitions transforming p-adic space-time sheets to real ones could be understood as a tunnelling through the intersection of the p-adic and real worlds: here zero energy ontology is absolutely essential in order to avoid the problems caused by the impossibility to compare directly real and p-adic quantum numbers and by the non-existence of p-adic conserved charges caused by the lack of definite integral (field equations however make sense). This would provide one candidate for the formation of cognitive representation on one hand and for the transformation of intention to action on the other hand. Only living matter could carry negentropic entanglement and evolution would take place in the intersection of p-adic and real worlds.

If one accepts the idea that living matter resides in the intersection of real and p-adic worlds it becomes easy to accept effective p-adic topology of real space-time sheets in turn justifying the hypothesis that evolution corresponds to p-adic evolution. Evolution could be seen as diffusion in the discrete space defined by primes and since the number of primes larger than given prime is infinite, evolution as the gradual increase of typical p-adic prime is unavoidable. This hypothesis is testable. The reason is that p-adic length scale hypothesis selects very few physically interesting primes in the range of biologically interesting length scales and makes the notion of p-adic evolution very predictive. The hierarchy of the p-adic primes should also correspond to the hierarchical structure of consciousness.

The infinite size of the universe forces to introduce the notion of infinite primes and corresponding p-adic topologies. Infinite primes have decomposition into finite primes labelling space-time sheets possessing p-adic topology. The notion of infinite prime allows to understand the evolution as two kinds of processes. First process is continuous and corresponds to a gradual increase of the finite p-adic prime associated with the existing physical system. Second process is discontinuous and involves the emergence of entirely new p-adic space-time sheets. The gradual increase of the cell size during evolution and the sudden emergence of multicellular structures provide examples of these two aspects of the evolution. The increase of the finite prime corresponds to a gradual refinement of the corresponding p-adic topology in the sense that the notion of nearness as it is realized at the level of conscious experience, becomes more and more refined. Also the maximum information content of conscious experiences increases with p-adic prime. Thus a measure for the complexity of a conscious system is in question. Identification of p-adic physics as physics of cognitive representations adds considerable concreteness to this vision and one ends up with rather concrete ideas about how thought is transformed to actions and sensory input is transformed to thought.

8.1.3 Self-Hierarchy, Quantum Self-Organization, And Dissipation As A Darwinian Selector

The breakthrough idea in TGD inspired theory of consciousness was the notion of self defined as a subsystem able to remain unentangled during the unitary quantum "time evolutions" U associated with quantum jumps $\Psi_i \rightarrow U\Psi_i \rightarrow \Psi_f$. The notion of self leads to the concept of self hierarchy and the interpretation of quantum self-organization as evolution of selves [K87]. Zero energy ontology implies that quantum states correspond to physical events in standard ontology. This means that self has extension in time direction and has causal diamonds (CDs) defined as intersections of future and past directed light-cones as embedding space-time correlates and space-time sheets within CDs as space-time correlates. Self corresponds therefore to a finite-sized object in both spatial and temporal directions and can be seen as a classical self-organization pattern at space-time level. Quantum jumps replace this pattern gradually with an asymptotic self-organization pattern.

The precise definition of self has remained a long standing problem and I have been even ready to identify self with quantum jump. Zero energy ontology allows what looks like a final solution of the problem. Self indeed corresponds to a sequence of quantum jumps integrating to single unit, but these quantum jumps correspond state function reductions to a fixed boundary of CD leaving the corresponding parts of zero energy states invariant. In positive energy ontology these repeated state function reductions would have no effect on the state 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 also to self. The first quantum jump to the opposite boundary corresponds to the act of free will or wake-up of self.

Nengentropy Maximization Principle combined with the possibility of positive entangleement negentropy favors the formation of entangled states in the intersection of real and p-adic worlds identified as living matter. If consciousness is not lost in quantum jump leading to negentropic bound state entanglement but expands instead, co-operation becomes a way to survive so that the selection of the fittest would mean also selection of the most un-selfish one. Unselfish genes would be the survivors.

A system possessing self (possibly having sub-selves) performs quantum jumps and dissipates. This leads to quantum self-organization leading to asymptotic patterns selected by dissipation, which thus acts as a Darwinian selector of both memes and genes. Actually, there is no deep difference between genes and memes (understood here rather metaphorically) since selves are always conscious systems and consciousness is present already at elementary particle level. In light of this, the notion of the self hierarchy should be of crucial importance for the understanding of living systems and the purpose of this chapter is to demonstrate this and also to propose a general view about how biological self hierarchy is realized dynamically.

One of the important consequences of the quantum self-organization is that it provides justification for the use of cybernetic notions in the description of bio-systems. Many neuroscientists (and even physicists!) who claim that it is possible to understand brain in terms of classical notions fail to realize that the notions used are very far from classical. For instance, Hodkin-Huxley equations for nerve pulse involve in an absolutely essential way dissipation. It is the very presence of self which makes dissipation possible! Actually any description involving kinetic equations and irreversibility instead of classical field equations implicitly assumes that system is part of self! In particular, the notions of feedback, neural circuits, excitation, inhibition, signalling,... are all notions, which are not possible in the context of classical physics. The basic signature of self is that it seems the world look like classical in the eyes of neuroscientist!

8.1.4 The Prerequisites For Macro-Temporal Quantum Coherence

Macroscopic and macro-temporal quantum coherence is an essential element of quantum consciousness theories: for instance, quantum coherence is necessary prerequisite for quantum bio-computation. The basic objection against these theories is that the de-coherence time, which tells in which time scale Schrödinger equation applies, is quite too short to allow macroscopic coherence in the required time scales which could be even of order.1 seconds [J59].

These arguments are however based on a theory, which contains an inherent logical contradiction (nondeterminism of quantum jump contra determinism of Schrödinger equation) and rely on standard physics. In TGD the mentioned contradiction disappears, and standard physics is replaced with a physics in many-sheeted space-time. In particular, zero modes and quantum spin glass degeneracy emerge as completely new elements absent from quantum quantum field theories, and these elements together with quantum criticality help to understand how macro-temporal quantum coherence is generated. A close relation with the ideas of Penrose and Hameroff results because spin glass degeneracy is due to the presence of a large number of space-time sheets differing only by their classical gravitational energy. Spin glass degeneracy is mathematically identical with a broken $U(1)$ gauge symmetry since CP_2 canonical transformations leaving induced Kähler form invariant and acting as approximate symmetries act like $U(1)$ gauge transformations.

The original belief was that one could do without further elements. This belief was wrong.

1. Zero energy ontology favors formation of macroscopic quantum phases. The notion of causal diamond (CD) explains p-adic length scale hypothesis assigning to elementary particles primary p-adic length scale of order Compton length. The size scale of CD itself corresponds to secondary p-adic length scale which is typically macroscopic even in the case of elementary particles. For electron the time scale in question is.1 second which corresponds to a length scale slightly below Earth's circumference. CDs define naturally macroscopic quantum systems and magnetic body is the natural candidate for this system. The time scale of CD defines the geometric time scale of memory and planned action and also the time scale naturally of quantum computation like processes assignable to self during quantum jump (unitary process U followed by a sequence of state function reductions leaving only bound state entanglement or negentropic entanglement).

2. Various anomalies related to living matter hower - in particular, the strange effects of ELF em fields on vertebrate brain, lead to a generalization of quantum theory by introducing a

hierarchy of Planck constants. The mathematical formulation requires a generalization of the notion of embedding space by replacing it with a book like structure with pages characterized partially by the values of Planck constant which can have arbitrary large values. In particular, the Planck constant associated with the space-time sheets mediating gravitational interactions has a gigantic value this means that all quantum scales are scaled up and macroscopic quantum coherence becomes possible even in cosmological time scales.

The model of DNA as topological quantum computer relies on the notion of magnetic body, CD, and the hierarchy of Planck constants [K5]. This hierarchy provides also the basic mechanisms of catalytic action and of the phase transitions characterizing gel phase. The reconnection of magnetic flux tubes is the first mechanism of this kind. Shortening or lengthening of the magnetic flux tubes in a phase transition changing the value of Planck constant is second key mechanism.

The fact that oxidative metabolism is anomalously low during a neuronal synchrony supports the view that neuronal synchrony might give rise to negentropic bound-state entangled multineuron states in "state of oneness" (the liberated binding energy would be usable energy). The quantum computations performed by the neuronal groups might last the typical duration of "feature", which is about .1 seconds, typical time scale of alpha rhythm. This also suggests that Cooper pairs of electrons are in crucial role. Also the breaking of second law of thermodynamics is predicted in time scale of the negentropic bound state. p-Adic length scale hypothesis actually suggests an entire hierarchy of breakings of second law occurring below p-adic time scale.

8.1.5 TGD Based View About Dark Matter

TGD suggests an explanation of dark matter as a macroscopically quantum coherent phase residing at larger space-time sheets [K36].

1. TGD suggests that $\hbar$ is dynamical and possesses a spectrum expressible as integer multiples of ordinary Planck constant. The criterion for transition to large $\hbar$ phase is the failure of perturbative expansion so that Mother Nature takes care of the problems of theoretician. A good guess is that the criticality condition reads as $Q_1Q_2\alpha \simeq 1$ where Q_i are gauge charges and α gauge coupling strength. This leads to universal properties of the large $\hbar$ phase. For instance, $\hbar$ is scaled in the transition to dark phase by a harmonic or subharmonic of parameter $1/v_0 \simeq 2^{11}$ which is essentially the ratio of CP_2 length scale and Planck length [K92, K36]. The criticality condition can be applied also to dark matter itself and entire hierarchy of dark matters is predicted corresponding to the spectrum of values of $\hbar$.

2. An infinite hierarchy of dark matters is predicted [?]. The basic hierarchy corresponds to the values of $\hbar$ coming as integer multiples of ordinary Planck constant $\hbar_0$. Direct interactions occur only between the particles characterized by integers having common p-adic prime factors characterizing the p-adic length scales of bosons exchanged in the interaction. The algebraic extensions of p-adic numbers define an additional hierarchy. Also the notion of darkness must be refined by attributes partial and relative.

3. From the point of view of nuclear physics application of this hypothesis is to QCD. The prediction is that the electromagnetic Compton sizes of dark quarks are scaled from $L(107)$ to about $2^{11}L(107) = L(129) = 2L(127)$, which is larger than the p-adic electromagnetic size of electron! The classical scattering cross sections are not changed but changes the geometric sizes of dark quarks, hadrons, and nuclei. The original hypothesis that ordinary valence quarks are dark whereas sea quarks correspond to ordinary value of $\hbar$ is taken as a starting point. In accordance with the earlier model, nucleons in atomic nuclei are assumed to be accompanied by color bonds connecting exotic quark and anti-quark characterized p-adic length scale $L(127)$ with ordinary value of $\hbar$ and having thus scaled down mass of order MeV. The strong binding would be due the color bonds having exotic quark and anti-quark at their ends.

4. Quantum classical correspondence suggests that classical long ranged electro-weak gauge fields serve as classical space-time correlates for dark electro-weak gauge bosons, which are massless below the appropriate weak length scale L_w. This hypothesis could explain the special properties of bio-matter, in particular the chiral selection as resulting from the coupling

to dark Z^0 quanta. Long range weak forces present in TGD counterpart of Higgs=0 phase should allow to understand the differences between biochemistry and the chemistry of dead matter.

5. For ordinary condensed matter quarks and leptons Z^0 charge are screened in electro-weak length scale whereas in dark matter $k = 89$ electro-weak space-time sheet have suffered a phase transition to a p-adic topology with a larger value of k. Gaussian Mersennes, in particular those associated with $k = 113, 151, 157, 163, 167$ are excellent candidates in this respect. The particles of this exotic phase of matter would have complex conformal weights closely related to the zeros of Riemann Zeta. The simplest possibility is that they correspond to a single non-trivial zero of Zeta and there is infinite hierarchy of particles of this kind.

   In dark matter phase weak gauge fluxes could be feeded to say $k = k_Z = 169$ space-time sheet corresponding to neutrino Compton length and having size of cell. For this scenario to make sense it is essential that p-adic thermodynamics predicts for dark quarks and leptons essentially the same masses as for their ordinary counterparts [K56].

8.1.6 Topological Field Quantization

Topological field quantization assigns to various quantum concepts rather precise geometrical correlates. Absolute minimization of Kähler action implies that the space-time surface associated with given 3-surface satisfies generalized Bohr rules so that something generalizing Bohr model of atom to the level of classical fields results as an exact part of the quantum theory. Also virtual and real particles of quantum field theories have classical correlates. In particular, virtual particles corresponds to cognitive space-time sheets representing geometric correlates for selves. Furthermore, topological field quanta are characterized by vacuum quantum numbers very much analogous to ordinary quantum numbers and topological field quantum defines a unique selection of quantization axes for spin and color quantum numbers.

The p-adic hierarchy of the space-time sheets indeed provides a geometrical and topological realization for the self hierarchy already discussed in detail in the previous chapter. The real power of the notion of topological field quantization came apparent, when it became clear that the topological field quanta associated with ELF em fields with frequencies in EEG frequency range must be correlates of our sub-selves (mental images). This means a radical reconsideration of the basic assumptions of neuroscience. What makes this radical rethinking unavoidable is that one can indeed understand the important frequencies of the EEG and one ends up with a precise quantitative model for cognition and sensory experience. In particular, a general quantum model of coordination and control emerges.

The most important topological field quanta are magnetic flux tubes which are identified as carries of super-conducting ionic BE condensates. They form a fractal hierarchy. Massless extremals (MEs) are second extremely important class of topological field quanta and are for radiation fields what Bohr orbits are for the atom. There is also a close connection with the geometric optics. MEs are ideal for communication purposes both at classical and quantum level. The light like boundaries of MEs are carriers of super-conformal and super-symplectic representations having gigantic almost-degeneracies broken only by the non-commutativity of Poincare transformations and super-symplectic transformations. The boundaries of MEs are quantum holograms in the sense of quantum gravity. The light like vacuum currents associated with MEs in turn define dynamical classical holograms and there are good reasons to expect that MEs make possible quantum teleportation of electromagnetic states. super-symplectic states are genuinely quantum gravitational states defined in the space of 3-surfaces whereas magnetic states (actually all states predicted by quantum field theories) can be effectively reduced to states associated with single 3-surface. This means that MEs are definitely above the super-conducting magnetic flux tubes in the hierarchy of consciousness and should control what happens at magnetic flux tubes. Perhaps our consciousness is associated with MEs whereas "body consciousness" would be associated with magnetic super-conductors.

The hypothesis that the topological field quanta associated with a material system provide a representation for the system's quantum properties provides a strong interpretational tool. For instance, electromagnetic transition frequencies should correspond to MEs having lengths equal to the transition wavelengths and binding energies should correspond to negative energy MEs with length determined by the binding energy. This topological self reference leads to the notion of field body. Any system has a field body which serves as a kind of manual providing a symbolic representation about the system: this representation is not possible in Maxwell's theory. In the case of DNA the field body provides a higher level representation of the genetic information. In the case of human body the field body provides among other things a representation for the state of brain: EEG MEs have lengths measured using Earth size as unit but also ULF MEs necessary for the realization of the long term memory and having lengths measured in light years are present. This picture inspires also the hypothesis that sensory representations are realized at the magnetic sensory canvas provided by the flux tubes or shell like topological field quanta of Earth's magnetic field. The magnetic mirrors formed by the magnetic flux tubes emanating from the body and parallel MEs serve as projectors to the magnetic sensory canvas.

8.1.7 Important Empirical Inputs And Overall View

The development of the ideas about quantum control has occurred in jump-wise way with jumps being induced by some crucial empirical inputs. My own meager knowledge about biology has certainly been one important factor hindering systematic development of the ideas.

Ironically, the needed empirical data providing direct evidence for the importance of the ionic super-conductors has existed already at seventies [J25] and I encountered them almost accidentally (at least it looks so)! Thanks for this are due to Gene Johnson from whom I learned a lot about brain as seen by neuroscientist. These data convincingly demonstrate that cyclotron resonance frequencies of various ions in Earth's magnetic field are very special. Electromagnetic fields at these frequencies or modulated by these frequencies have unexpected and poorly understood effects on living matter and brain. Even more, important EEG frequencies correspond to multiples of the cyclotron frequencies of the basic ions involved with the nerve pulse generation. Most importantly, the data provide the long sought-for direct evidence for bio-systems as macroscopic quantum systems! This empirical input made it possible integrate the bundle of ideas about bio-systems as macroscopic quantum systems to a general model of how coordination and control are realized in living systems.

A second decisive input where the observation that the frequencies of the BE condensed photons associated with the massless extremals (MEs) correspond in EEG frequency range to important EEG resonance frequencies if one assumes that p-adic length scales define preferred lengths for MEs [K85]. Together with the inspiration coming from the vision of Peter Marcer about bio-systems as quantum holograms [I54]. and the realization that the light like boundaries of MEs can be regarded as seats for so called super-symplectic representations providing huge information resources, this observation led to the realization that the fractal hierarchy of MEs must represent the highest control level in bio-system.

The third crucially important empirical input were the empirical findings challenging the notions of ionic channels and pumps [I63]. The explanation of these data led to a rather concrete model for homeostasis as a many-sheeted ionic flow equilibrium. This picture allows to understand how extremely low densities of super-conducting ions at super-conducting magnetic flux tube structures can control much higher ionic densities at atomic, non-super-conducting space-time sheets: the basic formula relates the ratio of densities of ions at atomic and super-conducting space-time sheet to the inverse of the corresponding flow velocities.

Coherent electric fields at atomic space-time sheets are required in order to have non-vanishing ohmic currents and this explains why bio-matter is liquid crystal having as a consequence also the electret property. In this picture one can understand also the role of DC current circuitry discovered already by Becker [J16]. Also the ideas of Mae Wan-Ho about control current circuitry formed by collagen network fits nicely with vision about many-sheeted ionic flow circuitry. A further support for this vision is provided by the empirical evidence for water memory and various effects involved with it [I22, I42, I43, I31]. Many-sheeted ionic flow equilibrium suggests an elegant mechanism of homeopathy: the extremely low densities of homeopathic remedies are at the controlling super-conducting space-time sheets where the control is. Thus homeopathy can be seen as a high precision medicine minimizing the amount of the remedy needed [K21, K22, K44] rather than some kind of magic treatment.

8.1.8 Quantum Coordination And Control And The Hierarchy Of MEs, Magnetic Super Conductors, Electrets And Bio-Matter

Basic dynamical aspects of a biological system relate to coordination and control. Coordination is involved with almost automatic and predictable activities involving no volition whereas control involves volition and non-predictability. Basic examples are coordination and control are EEG and nerve pulse respectively. Various motor activities are good examples of control involving macroscopic changes of the shape of the organ.

The basic question, to be addressed in this chapter, concerns about the dynamical realization of the coordination and control. The TGD inspired vision about bio-system is as a symbiosis of the fractal hierarchies of MEs and magnetic super-conductors, with bio-matter. MEs represent the highest hierarchy level controlling magnetic super-conductors which in turn control and coordinate the behavior of the non-super-conducting matter at atom space-time sheets by ionic flow equilibrium. Atoms of condensed matter can possess anomalous Z^0 charge vacuum screened in atomic length scale [K97, K38]. Also Z^0 super-conductivity is in principle possible: thus the control of also neutral atomic and molecular densities is possible. The control operations presumably involve momentary loss of flow equilibrium: the simplest control mechanism is "let it go for a moment".

The great challenge is to identify the basic mechanisms of quantum control and coordination.

1. TGD suggests strongly that the formation of join the along boundaries bonds between the space-time sheets possibly representing different levels of the self hierarchy could be one of the basic mechanism of control and coordination. The interpretation as a prerequisite of bio-feedback, understood in very general sense, is very suggestive. The presence of the join along boundaries bonds makes possible transfer of various particles between space-time sheets in question (for instance, atomic and super-conducting space-time sheets).

2. Space-time sheets connected by join along boundaries bonds form a system very similar to two (weakly) coupled super conductors connected by Josephson junctions. This suggests that that Josephson currents between the space-time sheets are crucial for the coordination. The Josephson currents would act effectively as an interaction Hamiltonian representing harmonic perturbation coupling to each other single particle state basis localized in either super conductor and having overlap only in the Josephson junctions. If the frequency of the Josephson current acting as a harmonic perturbation of super conductors, equals to the energy difference for single particle states of either super conductor, the standard rules of quantum mechanics predict the possibility of quantum jumps between these states. When the frequency of the Josephson current is not equal to energy difference, quantum jumps do not occur at the limit of an infinitely long interaction time. This suggests that harmonic perturbations provide a general mechanism of quantum coordination and control: by tuning the frequency of the Josephson current quantum master can "wake-up" the quantum slave. Large Josephson currents can induce failure of flow equilibrium and lead to non-equilibrium processes crucial for control.

3. Join along boundaries contacts can and must allow also the flow direct supra currents or Ohmic currents above critical velocity. SQUID type circuit is a good analog for the situation. A very natural interaction mechanism between MEs and super-conducting circuits is magnetic induction ($\Phi = LI$ modulo flux quantum), which induces supra-current guaranteeing the quantization of magnetic flux in the circuit. The em fields associated with MEs can also induce magnetic quantum transitions possibly amplified to quantum phase transitions. Of course, also other than magnetic quantum transitions might be amplified by the quantum coherence of the BE condensate. These transitions could very effectively modulate the chemical properties of, say enzymes. The super-conducting electrons at space-time sheets associated with the molecular space-time sheets could be in electronic flow equilibrium with atomic space-time sheets and control the conformation of the molecule very effectively. MEs in turn could control the supra-currents by magnetic interaction and thus the conformations of molecules. Thus the super-conducting magnetic flux tubes are tailor-made for biochemical control.

4. There is also a feedback loop from the magnetic super-conductors to MEs since quantum phase transitions induce emission of photons which can Bose-Einstein condense to MEs car-

rying collinear BE condensates of photons (and also gravitons). For instance, endogenous NMR spectroscopy and its generalizations could be possible in this way if magnetic flux tubes have varying thickness! This NMR might be basically responsible for chemical senses.

5. It took quite a long time to fully realize the obvious. Bio-systems are full of electrets and TGD indeed predicts the flux quanta of electric fields as basic solutions of field equations dual to the magnetic flux tubes. Also TGD counterparts of Tesla's scalar waves are predicted as special case of these solutions.

6. The newest and perhaps the most fundamental element of bio-control is time mirror mechanism. Many-sheeted space-time makes possible many-sheeted lasers since cold space-time sheets can contain Bose-Einstein condensates of ions and their Cooper pairs. If the system contains population inverted many-sheeted laser for which the increment of zero point kinetic energy corresponds to the energy of photons associated with negative energy MEs, the absorption of negative energy photons gives rise to a phase transition like dropping of particles to larger space-time sheet by the induced emission mechanism, and the control signal represented by negative energy MEs can be amplified if a critical number of particles drops to the larger space-time sheet. This control mechanism allows an instantaneous motor control in which intention is transformed to desired represented by negative energy MEs and generates in geometric past a reaction representing the desired response, say neuronal activity giving rise to motor action. This process probably involves entire hierarchy of magnetic selves realizing their intentions as desires communicated to lower level magnetic selves and the lowest level corresponds to the regions of brain responsible for liberating metabolic energy.

In this and next chapter my aim is to describe the general view about how quantum coordination and control in bio-systems is realized. In this chapter main emphasis is on super conductivity and many-sheeted ionic flow equilibrium. Next chapter is devoted to field aspect, to the time mirror mechanism as a means to transform intentions to actions, and to the role of classical Z^0 fields in living matter. Reader can find more details about various macroscopic quantum phases involved from subsequent chapters of the book. It must be emphasized that the picture is still evolving and I have not simply had time to integrate various elements in the big and complex picture to single coherent whole.

During last years a lot of new elements have entered the picture. ZEO affords new insights about quantum self-organization. A more detailed view about dark matter hierarchy $h_{eff} = n\times$ allows to see biophotons as ordinary photons resulting from dark photons and they play a key role in communications to and control by magnetic body. The notion of magnetic body provides a key notion in understanding self-organization as 4-D self-organization in ZEO and even replication can be reduced to that for magnetic body and regarded as 3-D analog of particle decay.

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` [L13].

8.2 Bio-Systems As Macroscopic Quantum Systems

Bio-systems contain quantum sub-systems, which can have macroscopic size. For example, organic polymers, nerve cell, muscle fiber and brain could be systems of this kind. The formation of the larger quantum systems from smaller ones is achieved by the join along boundaries bond. At molecular level this corresponds to the formation of a chemical bond [I81] so that macromolecules result. At cell level this means that the lipids and/or proteins of the layers of the cell membrane are joined together by chemical bonds. At the level of organ, say brain, a good candidate for the flux tube is gap junction [J53] joining neighboring cells together. These gap junction connected structures are very general in bio-system. For instance, sensory organs are gap junction connected structures of neurons and also brain contains these structures.

8.2.1 # Contacts As A Macroscopic Quantum System?

The original wrong belief was that wormhole contacts represent something genuine new. First it became clear that the light-like throats of wormhole contacts (see **Fig.** `http://tgdtheory.fi/`

`appfigures/wormholecontact.jpg` or **Fig. ??** in the appendix of this book) are natural carriers of fermionic quantum numbers. Later came the realization that bosons and their super-partners have a natural identification as wormhole contacts whereas fermions and their superpartners correspond to wormhole throats assignable to topologically condensed CP_2 type extremals. This implies the notion of bosonic emerges meaning that gauge bosons and their super-partners are not fundamental entities: this has powerful implications for quantum TGD . This result does not mean that all wormhole contacts allow interpretation in terms of elementary particles and there are good reasons to expect that in living matter wormhole contacts define an entire spectroscopy of elementary particle like entities having masses determined by the appropriate p-adic length scale. A possible interpretation is as scaled variants of quarks, leptons and gluons defining a hierarchy of copies of say QCD type physics.

An excellent candidate for a macroscopic quantum system is provided by # contacts (or wormhole contacts). # contacts must have small inertial mass, which by a dimensional argument must be of order $1/L(n)$, where $L(n)$ is the lower bound for the size of a typical 3-surface at a given condensation level. The presence of the energy gap, given by the rest mass of the # throat, suggests that they can form Bose Einstein condensates located on the boundaries of the 3-surface.

Charged # contacts are especially interesting in this respect. They couple extremely weakly to radiation fields, which explains why they have not been observed and also implies that the BE condensate of # contacts is thermally isolated from the ordinary matter. The coupling to the difference of the classical gauge potentials associated with the two space-time sheets connected by them can give rise to a relatively strong, purely classical interaction. Therefore charged # contacts behave very much like Cooper pairs and the concepts of Josephson current and Josephson junction generalize. # contacts are located near the boundaries of the smaller 3-surface and appear in all length scales. These properties make # contacts an ideal tool of bio-control at quantum level and it might well be that they appear in all the relevant scales associated with the bio-systems.

contacts couple to the difference of the gauge potentials serving as order parameters for the coherent photons topologically condensed on the two space-time sheets connected by # contact and this suggests that the coupling of # contacts to coherent light might serve as a important biological function. Indeed, this kind of coupling provides an explanation for the so called Comorosan effect involving an interaction between laser light and organic molecules, which is not understood in the standard physics context [I92, I33].

The so called wormhole magnetic fields are two-sheeted structures with finite spatial size containing magnetic fields of same magnitude but opposite direction at the two space-time sheets involved. The magnetic fields are created by wormhole currents residing at the boundaries of the structure. Wormhole magnetic might also have a key role also in bio-systems in providing simplest possible almost vacuum space-time surface of finite spatial size serving as a concrete model for association sequence. For instance, axons and various other linear structures could correspond to the concentrations of ordinary matter around the flux tubes of magnetic or even wormhole magnetic fields. Wormhole magnetic fields provide cognitive representations and the simplest representation is direct mimicry. Thus mind like space-time sheets could carry classical fields of same intensity as material space-time sheets but having as their sources currents of wormhole contacts: this kind of mechanism could provide explanation for some exotic effects like homeopathy [K121].

8.2.2 Do Micro-Tubuli Act As Quantum Antennae?

Micro-tubuli are believed to play key role in the information processing of the cell and there are lots of speculations about the possibility that micro-tubuli are mesoscopic quantum systems. In TGD context there is indeed a very general mechanism leading to the generation of the coherent photons and gravitons. The point is that the classical induced gauge fields need can give rise to non-vanishing vacuum currents generating coherent states of photons or gravitons. The many-sheeted nature of space-time suggests the presence of almost vacuum space-time sheets and the so called massless extremals studied in [K70] provide an excellent candidate for an almost vacuum space-time leading to the generation of coherent photons and gravitons. The simplest massless extremals are cylindrical structures and the vacuum gauge currents run along the cylinder with light velocity. Also the Einstein tensor is light like. The frequencies of the coherent photons come as multiples of π/L, where L is the length of the structure. These cylindrical structures clearly act as quantum antennae both sending and receiving coherent photons.

Micro-tubuli represent an important example of a linear bio-structure and an attractive possibility that they are accompanied by a space-time sheet, which is in a good approximation massless extremal having weak coupling to the ordinary space-time sheets containing the bio-matter and thus providing a representation for some aspects of the exterior world in the properties of the vacuum current. Of course, also DNA and other linear structures could act as quantum antennae and quantum antenna mechanism might be completely generic and length scale independent mechanism in the bio-systems.

8.2.3 Classical Z^0 Force, Neutrinos And Chiral Selection

The arguments related to the smallness of the parity breaking effects in nuclear, atomic and molecular length scales led to the assumption that elementary particles feed their Z^0 gauge charges to the condensate levels having $L(k) \geq L(k_Z) \geq \xi \simeq 4 \times 10^{-6}\ m$: this length scale corresponds to the cell length scale and also to the Compton length for neutrinos having mass of order one eV. The simplest assumption is that all Z^0 charge is fed at this level. Classical Z^0 force is screened by the neutrinos and a model for the destruction of the super fluidity by Z^0 magnetic vortices leads to the rough estimate $\epsilon_Z \in (10^{20} - 20^{22})$ for the parameter ϵ_Z describing screening ($1/\sqrt{\epsilon_Z}$ is the ratio of unscreened Z^0 charge density to the nuclear Z^0 charge density).

The appearance of the classical Z^0 force suggests an explanation for the chirality selection of the organic molecules taking place in vivo. Very roughly the idea is as follows: the axial part of Z^0 field couples to the spin of neutrinos. Parity breaking effects are small unless there is a net magnetization of neutrinos and this magnetization could be caused by the classical Z^0 magnetic fields inside the cell. These magnetic fields can be strong since they are caused by the moving nuclear Z^0 charge (neutrinos probably do not follow the motion of matter). The tritium beta decay anomaly [K97] provides direct evidence for the presence of classical Z^0 force in condensed matter systems. The magnetized regions in turn could have interpretation as "thinking regions" of space-time in accordance with the interpretation of fermionic state basis as Boolean algebra.

8.2.4 Are Bio-Systems Super-Conductors?

The interpretation of the state basis (2^N states) of the fermionic Fock space generated by N creation operators as a Boolean algebra of statements about N basic statements suggests that quantum jumps in the fermionic sector might have something to do with Boolean and quantitative aspects of consciousness. Quantification is here understood as an ability to associate to sensory experience an integer represented as a bit sequence such that bit is represented as the value of fermion number or as the direction of fermion spin. This conforms with the earlier speculations about the fundamental role of defects in type I neutrino super conductors if one identifies defects as "thinking" regions, where Fock basis is natural whereas in super-conducting phase basic particles are bosons. As suggested already earlier, one could also interpret the almost topological vacuum quantum numbers characterizing the magnetic flux associated with the defects as a biologically relevant information. Cell membranes and endoplasma membranes having local stripe like structure indeed resemble defects in type I superconductors. A tentative guess is that bio-systems can be both electronic and neutrino super conductors and that there exist magnetic and/or Z^0 magnetic fields in these regions leading to ordinary and/or Z^0 magnetization.

Atomic space-time sheets are not expected to be electronic super-conductors for obvious reasons but the space-time sheets with larger size contain very small charge densities and super conductivity at these space-time sheets might be possible. A mechanism leading to the presence of electrons at "non-atomic" space-time sheets would be the "dropping" of the atomic electrons to the larger space-time sheets so that "exotic atoms" are formed. "Dropping" could take place via a temporary formation of flux tubes connecting the space-time sheets in question: in this case exotic phases are probably near the boundaries of the larger space-time sheet. If valence electrons are in question, this phenomenon leads to "electronic alchemy". The formation of the exotic atoms is necessarily accompanied by a destruction or a formation of charged # contacts or their flow between space-time sheets joined together by join along boundaries bonds since the net charge of the atomic space-time sheet changes.

A possible mechanism leading to the formation of the Cooper pairs is analogous to the ordinary mechanism based on the phonon exchange. The Coulombic and magnetic interaction of electrons with the # contacts generating the excitations of the # contact BE condensate is analogous to the induction of phonon exchange by the electron-nucleus classical electromagnetic interaction and could give rise to an attractive force between electrons. Since the space-time sheets in question are almost empty, the Cooper pairs could be even thermally shielded. The large value of the gap energy could also make the super conductor in question stable.

Also ionic superconductivity relying on the dropping of ions to "dark" space-time sheets is possible and supported by empirical findings. The first observations about the special effects of ELF em fields on brain at cyclotron frequencies of ions Na_+, Cl^-, K_+, Ca_{++} and electron in Earth's magnetic field to brain were made already at seventies [J25]. These experiments suggest strongly that these ions/their Cooper pairs are confined in the magnetic field of Earth and form bound states with macroscopic size of order cell size and extremely small binding energy corresponding to frequency of order 10 Hz. This is certainly not possible in the standard physics framework but can be understood as resulting from the dropping of ions and electrons from the atomic space-time sheet to the space-time sheet of the cell where the density of the matter is very low. There is very cold, dry and silent at the cellular space-time sheets and this makes possible macroscopic quantum phases formed by Cooper pairs of ions Na_+, Cl^-, K_+ and electron as well as well as Ca_{++} ions. Also other ions are possible but these ions are especially important for EEG.

In many-sheeted space-time (see **Fig.** `http://tgdtheory.fi/appfigures/manysheeted.jpg` or **Fig.** 9 in the appendix of this book) particles topologically condense at all space-time sheets having projection to given region of space-time so that one can speak about transfer only near the boundaries of space-time sheet of a given system. Also p-adic phase transition increasing the size of the space-time sheet could take place and the liberated energy would correspond to the reduction of zero point kinetic energy. Particles could be transferred from a portion of magnetic flux tube portion to another one with different value of magnetic field and possibly also of Planck constant h_{eff} so that cyclotron energy would be liberated.

Besides magnetic cyclotron frequencies Z^0 magnetic cyclotron frequencies and even wormhole cyclotron frequencies make sense: Z^0 currents for ions indeed induce automatically also ionic currents. One can quite well consider the possibility that neutral atoms and their Cooper pairs give rise to Z^0 superconductors, or equivalently, super fluids.

The effects related to water memory and claimed effects of homeopathy [I31] suggest that not only ions but only molecules (such as proteins) could form BE condensates at the magnetic flux tubes: these effects are discussed in detail in [K21, K22]. This would obviously open fantastic possibilities as far as quantum level bio-control is considered. A strong support for the notion of many-sheeted space-time and super-conductivity at non-atomic space-time sheets comes from the findings challenging the notions of ionic channels and pumps [I63] (see [K21, K22]).

In case of neutrinos, the interaction with the atomic nuclei via classical Z^0 magnetic fields induces phonon exchange mechanism essentially identical to the ordinary mechanism of superconductivity and the effective absence of Z^0 quanta makes the situation ideal for super conductivity. The breaking of neutrino super-conductivity could be caused in the cell membrane length scale by nuclear Z^0 magnetization leading to the generation of strong Z^0 magnetic fields: the same mechanism would also explain the chirality selection in living matter. According to quark model estimates, also proton has large anomalous Z^0 magnetic moment, so that ordinary magnetization could be accompanied by Z^0 magnetization.

8.2.5 Are All Magnetic Transition Frequencies Important For The Understanding Of Conscious Experience?

The empirical observations relating to the effects of ELF em fields suggest that multiples of cyclotron frequencies are important for living matter. In fact, also more general magnetic transition frequencies are expected to be important since ions can also have spin and this means that they interact with magnetic and Z^0 magnetic fields. This suggests that magnetic transition frequencies expressible could play a key role in the quantitative understanding of the physical correlates of conscious experience. In fact, one might hope of being able to characterize conscious experiences in terms of various quantum number changes occurred in the quantum jumps so that the idea that quantum jump between initial and final quantum histories determines the contents of consciousness would be realized in a precise quantitative manner. Consider next the generalization implied by taking into account spin.

1. The charge carries of various ionic superconductors can indeed have net spin. The Cooper pairs of electronic high T_c super conductors are in $J = 2$ state which means that the spins of the Cooper pairs for spin 1 state if orbital momentum is 1. This suggest that also the Cooper pairs of bio-super-conductors could have spin $J > 0$. In case of ionic super-conductors the spin can be $J = 2$ even in relative S state. The situation for proton and neuron Cooper pairs is same as for electrons. The magnetic interaction energy $E = \mu \cdot B$ splits the energies of spin degenerate states and spins are parallel to magnetic field in ground state. Thus Earth's magnetic field is expected to cause spontaneous magnetization. It turns out that the spin flip transitions of cognitive antineutrinos in the Z^0 magnetic field of axons are fundamental for the understanding cognition and hearing in TGD framework.

2. Larmor frequency which characterizes the nuclear contribution of this interaction to energy, is related to cyclotron frequency of singly ionized atom by

$$\omega_L = g\frac{S_z}{2}\omega_c \ ,$$

   where S_z is the projection of spin in the direction of magnetic field and g is Lande factor, which equals to $g = 1$ in the ideal classical case for which spin corresponds to angular momentum. For elementary fermions $g = 2$ holds true. Nuclear contribution is the dominant contribution for ions Na_+, K_+, Cl_- since electron shell is full for the ions in question. For Ca_{++} spin and magnetic moment vanishes.

3. Since Earth's magnetic field is very weak and Larmor frequencies are of same order of magnitude as cyclotron frequencies, Josephson currents might serve as harmonic perturbations inducing transitions between different spin states. The energies associated with the magnetic transitions are even multiples of Larmor frequency so that transitions changing the direction of spin of Cooper pair are induced by frequencies

$$f = (2n+1)f_c + 2\frac{\Delta S_z}{S}f_L = (2n+1+g\frac{\Delta S_z}{2})f_c \ .$$

   Odd multiples of cyclotron frequency are possible in the first order perturbation theory whereas even multiples are possible only in the second order of perturbation theory. For electron $g = 2$ in excellent approximation and the Larmor frequency is very nearly identical with cyclotron frequency. The deviation $\Delta g/g = \alpha/2\pi$ in lowest order of perturbation theory ($\alpha \simeq 1/137$) and thus the frequency for $n = -1$ transition changing the direction of the spins of the Cooper pair is $f \simeq 902$ Hz, which corresponds to the time scale of nerve pulse and of memetic codon [K43]. Since electron corresponds to Mersenne prime M_{127} associated also with the memetic code, the identification or the duration of single bit of memetic codon as $1/f$ is attractive.

4. Josephson currents which can induce cyclotron resonance could also induce more general quantum jumps changing the spin direction but inducing no change in orbital degrees of freedom at Josephson frequencies not far from cyclotron frequency. Note that these transitions are possible also for neutrons since they possess magnetic moment. For proton and neutron the Lande factors are $g(p) = 5.58$ and $g(n) = -3.82$ so that the corresponding Larmor frequencies in Earth's magnetic field would be 838 Hz for proton and 570 Hz for neuron.

5. Also the total spins ($J = 0, 1, 2, 3$) associated with the Cooper pairs of Na_+, Cl_- and K_+ ions having $J = 3/2$, can flip. The corresponding frequency scale is by a factor of order A (atomic number) higher than cyclotron frequency scale since the magnetic moment of nucleus is determined essentially by the magnetic moments of nucleons with unpaired spins.

8.2.6 Dark Counterpart Of The Earth's Magnetic Field As Carrier Of Ionic Bose-Einstein Condensates

The original model for the effects of ELF em fields on vertebrate brain was based on the hypothesis that the ELF frequencies in question correspond to the harmonics of cyclotron frequencies of ions in the Earth's magnetic field B_E. The development of the vision about dark matter [K37] led to the realization that the macroscopic quantum phases in question are dark matter identifiable as phases with an abnormally large value of Planck constant.

TGD predicts the spectrum of Planck constant(s) (one for M^4 and one for CP_2 type quantum numbers) as integer multiples of the ordinary Planck constant. There is also a spectrum of number theoretically preferred values of Planck constant [K40] which seems to be highly relevant for the understanding of the physics of living matter [K37]. The flux quanta of magnetic field carrying dark matter as macroscopic quantum phases controlling living matter would be responsible for bio-control. The natural question whether this dark magnetic field can be identified as the magnetic field of Earth. The answer to the question came via a detection of a calculational error as progress often comes.

For years I erratically believed that the magnitude of the magnetic field assignable to the biological body is $B_E = .5$ Gauss, the nominal value of the Earth's magnetic field. Probably I had made the calculational error at very early stage when taking Ca^{++} cyclotron frequency as a standard. I am grateful for Bulgarian physicist Rossen Kolarov for pointing to me that the precise magnitude of the magnetic field implying the observed 15 Hz cyclotron frequency for Ca^{++} is .2 Gauss and thus slightly smaller than the minimum value.3 Gauss of B_E. This value must be assigned to the magnetic body carrying dark matter rather than to the flux quanta of the Earth's magnetic field. This field value corresponds roughly to the magnitude of B_E at distance 1.4R, R the radius of Earth.

Dark matter hierarchy leads to a detailed quantitative view about quantum biology with several testable predictions [K37] . The applications to living matter suggests that the basic hierarchy corresponds to a hierarchy of Planck constants coming as $\hbar(k) = \lambda^k(p)\hbar_0$, $\lambda \simeq 2^{11}$ for $p = 2^{127-1}$, $k = 0, 1, 2, ...$ [K37]. Also integer valued sub-harmonics and integer valued sub-harmonics of λ might be possible. Each p-adic length scale corresponds to this kind of hierarchy. Number theoretical arguments suggest a general formula for the allowed values of λ [K40] as $\lambda = n$ where n characterizes the quantum phase $q = exp(i\pi/n)$ characterizing Jones inclusion [K118]. The values of n for which quantum phase is expressible in terms of squared roots are number theoretically preferred and correspond to integers n expressible as $n = 2^k \prod_n F_{s_n}$, where $F_s = 2^{2^s} + 1$ is Fermat prime and each of them can appear only once. $n = 2^{11}$ obviously satisfies this condition. The lowest Fermat primes are $F_0 = 3, F_1 = 5, F_2 = 17$. The prediction is that also n-multiples of p-adic length scales are possible as preferred length scales. The unit of magnetic flux scales up as $h_0 \rightarrow h = nh_0$ in the transition increasing Planck constant: this is achieved by scalings $L(k) \rightarrow nL(k)$ and $B \rightarrow B/n$.

$B = .2$ Gauss would corresponds to a flux tube radius $L = \sqrt{5/2} \times L(169) \simeq 1.58L(169)$, which does not correspond to any p-adic length scale as such. $k = 168 = 2^3 \times 3 \times 7$ with $n = 5$ would predict the field strength correctly as $B_{end} = 2B_E/5$ and predict the radius of the flux tube to be $r = 18$ μm, size of a large neuron. However, $k = 169$ with flux $2h_5$ would be must more attractive option since it would give a direct connection with Earth's magnetic field. Furthermore, the model for EEG forces to assume that also a field $B_{end}/2$ must be assumed and this gives the minimal flux h_5. Note that $n = 5$ is the minimal value of n making possible universal topological quantum computation with Beraha number $B_n = 4cos^2(\pi/n)$ equal to Golden Mean [K6].

The natural working hypothesis is that $B_{end} = 2B_E/5$ holds true as a time average and that B_{end} defines the dark counterpart of the Earth's magnetosphere.

8.2.7 Massless Extremals

The so called "massless extremals" (MEs) are basic solutions of field equations associated with Kähler action [K70]. MEs describe propagation of one-dimensional nondispersive wave with light velocity and are accompanied by light like vacuum current generating coherent photons and gravitons. Since the vacuum current behaves in a non-deterministic manner at given point of ME, it is ideal for the coding of classical information. MEs can appear also as pairs of space-time sheets such that the two space-time sheets have opposite time orientations and hence also energies so that the net energy of ME pair vanishes. MEs define a fractal hierarchy starting from elementary particle length scales and extending up to cosmic length scales. MEs have light like boundaries carrying super-symplectic

One can assign to the light like boundaries of MEs representations of super-conformal and super-symplectic algebras. Super-symplectic symmetry is thus transformed from a cosmological symmetry to an ordinary macroscopic symmetry. Apart from small gravitational effects, super-symplectic degrees of freedom commute with the translational degrees of freedom. Physical states associated with MEs correspond to Bose-Einstein condensates of collinear photons and gravitons (these degrees of freedom correspond to quaternion conformal degrees of freedom explaining elementary particle quantum numbers) having an additional super-symplectic degeneracy. super-symplectic states can be interpreted as quantum holograms storing quantum information to the light like boundary of ME, which is thus analogous to the moment of big bang at the cosmological level.

The energies of BE condensed photons and gravitons come as multiples of $E = \pi/L$, where L is the length L of ME. p-Adic length scales $L_p(n) = p^{n/2}L_p$ for $p \simeq 2^k$, k power of prime, define a preferred set of lengths for MEs, and this means quantization of the fundamental transition frequencies involved with the transitions of photonic and gravitonic BE condensates as multiples of $f(p,n) = \pi/L_p(n)$. Rather amazingly, in ELF range these frequencies correspond to resonant EEG frequencies!

The super-symplectic degrees of freedom commute with Poincare algebra apart from gravitational effects which means a gigantic almost-degeneracy of states. This means that super-symplectic states can provide huge entanglement negentropy resources crucial for quantum computation and communication type operations as well as for cognitive representations. Thus super-symplectic representations can be interpreted as quantum level articulation for the statement that TGD Universe is quantum critical quantum spin glass. Super-symplectic representations clearly provide an excellent candidate for an infinite hierarchy of life forms. These life forms are labelled by three integers (k,m,n): physically interesting primes correspond to $p \simeq 2^{k^m}$, whereas k prime and m and n are integers. Perhaps it is these life forms which make mind like space-time sheets living creatures and these life forms emerge already in elementary particle length scales and become increasingly complex when the p-adic length scale increases. If so, life could be regarded as a symbiosis of these life forms with lower level life forms associated with super-conducting magnetic flux tubes.

These life forms ("mind")interact with each other, super-conducting magnetic flux tubes and ordinary matter via coherent light and gravitons and the classical gauge fields associated with MEs. MEs indeed act as receiving and sending quantum antennae and the light like classical vacuum currents associated with MEs allow to understand the classical aspects of dynamical quantum holograms and of quantum communications made possible by MEs.

MEs can also serve as Josephson junctions between magnetic flux tubes. MEs interact with super-conducting magnetic flux tube circuitry also by magnetic induction analogous to the interaction of brain's magnetic fields with SQUIDs. MEs can induce also magnetic quantum transitions. These interaction mechanisms could explain the observed intensity windows in the interaction of ELF em fields with bio-matter [J23]. Also

The natural identification of MEs as building blocks of cognitive structures leads to rather concrete model for long term memory and forces the hypothesis that MEs define an infinite hierarchy of electromagnetic life forms living in symbiosis with each other and bio-matter. The model allows to understand EEG as a direct physical correlate of mind like space-times sheets (MEs) associated with ELF selves and provides a general vision about the electromagnetic organization of brain as sensory and motor organ of higher level self. Also so called RF (radio frequency) and MW (microwave) MEs representing our mental images are crucial for the model. MEs are also crucial in the model of qualia. MEs are present also below cellular length scales and even at molecular level.

The model of qualia leads to rather detailed view about the sizes of the hierarchy of various MEs defining what might be called our electromagnetic body. It took long time to answer the question whether we should identify ourselves with the self associated with brain; with the entire body; with ELF ME having size at least of order Earth circumference; with ULF ME having size of order order light years from the fact that we have long term memories in time scale of lifetime; or with self having literally infinite size. The last two options seem to be more plausible than the first three: the illusion that we are nothing but our physical bodies is created by the fact that during wake-up state sensory input is about the region surrounding our body.

8.3 Many-Sheeted Space-Time Concept And Topological Aspects Of Quantum Control

Many-sheeted space-time concept is crucial for TGD inspired theory of consciousness and should allow to understand the topological aspects of quantum control. Topological field quantization is perhaps the most essential aspect involved and together with the preferred extremal property it implies rather precise correspondence between quantum and classical, including generalized Bohr rules for classical field configurations. Unfortunately, the extreme complexity of the dynamics does not allow to say much at detailed quantitative level. Quantum self-organization however comes in rescue and tells that physically interesting configurations corresponds to the asymptotic self-organization patterns selected by dissipation. This means that it should be possible to engineer asymptotic configurations by gluing together space-time sheets representing simple, highly symmetric solutions of the field equations associated with Kähler action.

8.3.1 How Bio-Systems Might Apply The Many-Sheeted Space-Time Concept?

Many-sheeted space-time concept makes possible several exotic new physics effects. The first ideas which come into mind are antigravity machines, energy production with apparent efficiency larger than one by generation of negative energy space-time sheets, coherent motion via generation of negative energy space-time sheets having large momentum and even communication backwards in geometric time seem to be in principle possible in TGD Universe. Many-sheeted space-time makes combined with super-conductivity makes also possible mechanisms of bio-control relying on many-sheeted flow equilibrium and the strange findings challenging the notions of ionic pumps gelcell provide support for this notion. The application of these mechanisms might make living systems what they are.

Possible new physics effects related to the TGD space-time concept

TGD based concept of space-time predicts several new effects.

1. One of the basic predictions of TGD is the possibility of classical Z^0 fields having Z^0 charges as their sources. Rotating macroscopic objects should generate Z^0 magnetic fields and this suggests that the behavior of rotating objects should exhibit anomalies. A special signature of effects of this kind is parity breaking caused by the parity breaking couplings of classical Z^0 field.

2. The mere rotation of a 3-surface carrying magnetic or Z^0 magnetic fields should induce electric or Z^0 electric fields whose divergence gives rise to vacuum charge density. Charge conservation suggests that this gauge flux must flow to a second space-time sheet carrying opposite net charge.

3. In TGD the time orientation of given space-time sheet need not be the standard one and this allows the possibility of negative classical energies. If this kind of space-time sheets are created, energy production with apparent efficiency greater than unity becomes possible. At the space-time sheets with negative time orientations classical fields should propagate from future to past making in principle possible to see to the geometric future of, say, astrophysical objects.

4. A further TGD based element is related to the fact that 3-surface can be regarded as a generalization of a point like particle. This means that 3-surface behaves like single coherent whole: in particular, classical fields oscillating coherently in arbitrary long length scales are possible and can give rise to an apparent propagation of effects with infinite velocity. The notion of pair creation from vacuum generalizes. For instance, pairs of space-time sheets with vanishing total classical energy can be created from vacuum. This kind of mechanism leads to a concrete idea about how bio-systems might generate energy ("buy now, pay later").

5. In TGD classical gauge fields and gravitational fields at a given space-time sheet are extremely tightly correlated since all these fields are expressible in terms of CP_2 coordinates and their gradients. Therefore the generation of magnetic and electric fields could induce perturbations of the classical gravitational fields having amplitudes gigantic as compared to those possible in General Relativity. In this kind of situation imbeddability requirement could force the system to feed part of its gravitational flux to some other space-time sheets. These effect might make possible antigravity effects in which the gravitational flux of Earth or test body is partially channelled to some other space-time sheet. An interesting possibility is that bio-systems could apply this kind of effects.

Some anomalies explained by TGD based space-time picture

It has gradually become clear that there is extensive literature about anomalies possibly having TGD based explanation [K14].

1. There are several TGD based mechanisms which could contribute to the effective gravity modification effects reported by Podkletnov [H24] and Schnurer Schnurer and Z^0 force might be involved with the effect.

2. Allais [E2, E10] observed that the oscillation plane of Foucault pendulum changes during solar eclipse. NASA performed the same experiment during 1999 eclipse but the processing of the data is still going on. Z^0 MEs emitted by Sun provide a model explaining basic qualitative facts.

3. There are anomalies related to the behavior of rotating gyroscopes [H14], [J61] suggesting that rotating gyroscope can lose part of its weight. TGD based mechanism is following: gyroscope channels part of its gravitational fluxes to some other space-time sheets than the one where it resides and, in the case that the receiving space-time sheet contains only very weak gravitational fields, gyroscope effectively loses part of its weight. Also the re-channelling of Z^0 fluxes might be involved.

4. There are quite puzzling observations related to the behavior of rotating stars [H22]. These observations are in a dramatic conflict with the standard wisdom about finite propagation velocity of signals and with the idea that classical fields propagate in future direction only. The possibility of space-time sheets with negative time orientation, and classical fields propagating from geometric future to geometric past and the possibility that 3-surfaces of even astrophysical size can behave like particle like objects, could explain these mysterious effects.

5. There are a claims about energy production with apparent efficiency larger than unity [H3, H7] by machines which contain rotating magnets. TGD requires generation or existence of space-time sheet carrying charge opposite to the vacuum charge induced by the rotation. If this space-time sheet has negative time orientation, it has negative classical energy and the energy of the material space-time sheet must increase by the requirement of energy conservation.

6. Biefeld-Brown effect is one of the oldest poorly understood anomalous effects [H4, H12]. What happens is that charged capacitor gains center of mass momentum in the direction orthogonal to the plane of the capacitor plates. It seems that the change of the effective gravitational weight of the capacitor based on redistribution of the gravitational and Z^0 fluxes cannot explain the entire effect. Rather, also the generation of a negative energy space-time sheet with net momentum associated with classical gauge fields could be involved. So called “massless extremals” are optimal candidates for this purpose. This mechanism might be applied by bio-systems to generate coherent motions.

Basic new physics mechanisms possibly applied by bio-systems

There are several candidates for new physics mechanisms applied by bio-systems.

How bio-systems are able to move coherently?

The ability of bio-systems (70 per cent of water!) to generate coherent motions is complete mystery from the point of view of standard physics describing bio-system as a soup of randomly moving atoms and molecules. The generation of negative energy space-time sheets with large net momentum compensated by opposite momentum of material space-time sheet provides a candidate for a mechanism making coherent motion possible. Negative energy space-time sheets could actually correspond to mind like space-time sheets: perhaps those representing the thought "I want to move to that direction" ! If this were the case, then this mechanism could be, somewhat loosely, said to provide the basic geometric counterpart for the interaction between matter and mind.

As will be found in the chapter [K70], the generation of so called "massless extremals" provides an optimal mechanism for coherent motion. The reason is that massless extremals have maximal possible classical momentum ($E = P$ holds true) so that the generation of space-time sheet corresponding to massless extremal gives large momentum to the material space-time sheet.

Negative energies are not absolutely essential for generating coherent motions. However, if massless extremals have positive energies, the efficiency of energy usage is however very low, approximately $\beta/2$, where β is the velocity generated: something like 10^{-8} if velocity is of order one meter per second. It could quite well be that massless extremal is created only for the period of time that motion lasts: this in accordance with the idea that classical counterparts of virtual particles are in question. Since the surplus energy generated on the material space-time sheet is partially dissipated during this time interval, this mechanism requires that metabolism feeds energy to the system to compensate this loss. Thus there is no contradiction with the general wisdom about the necessity of metabolic energy feed.

Generation of metabolic energy from vacuum?

If bio-systems can generate negative energy massless extremals, a very efficient generation of metabolic energy from vacuum becomes possible in principle. This principle could be called "buy now, pay later" principle since the lifetime of negative energy space-time sheets is expected to be finite. This suggests that generation of negative energy space-time sheets is rare process and that lifetimes of negative energy space-time sheets are finite. There is a lot of anecdotal evidence about the ability of yogis and mystics to survive without eating [J65]. The explanation often proposed by yogis themselves [J65] is that the energy of light replaces the usual sources of the metabolic energy. Standard science sceptics of course "know" and ridicule all this but, against the background of new physics predicted by TGD, I cannot avoid asking myself whether there might be some seed of truth behind these claims.

Communication backwards in time?

Negative energy space-time sheets have negative time orientation. This suggests that classical fields could propagate backwards in time. Combining this with the TGD view about universe as four-dimensional society with mind like space-time sheets dispersed around entire many-sheeted space-time, one ends up with the idea that communication backwards in geometric time could be possible and be based on generation of propagating classical fields. We could send messages to future along positive energy space-time sheets and receive answers to our messages (probably mostly questions!) along negative energy space-time sheets. An interesting possibility is that this kind of communication in short time scales is actually basic aspect of living systems making for them possible to predict what would happen in future if no quantum jumps between histories would occur. This kind of communication could provide an alternative explanation for the causal anomalies observed by Radin and Biermann [K116, **?**]. Note however that quantum jumps between quantum histories picture provides an alternative TGD based explanation for these effects. In any case, if communication backwards in time is really possible, human kind would be at the verge of an evolutionary step whose consequences are impossible to imagine.

Of course, it might be that genuine communication requires quanta, say photons. It seems that the coherent photons generated by negative energy massless extremals should possess negative energies so that the roles of the creation and annihilation type operators would be changed for photons glued to negative energy space-time sheets. If this were the case, one could also consider the possibility of communication based on negative energy photons wandering along negative energy space-time sheets.

Bio-systems as antigravity machines?

In [K110] it is found that TGD provides several mechanisms making possible what look like antigravity effects. Bio-system could get rid of part of its effective gravitational mass by feeding part of its gravitational flux to an almost empty space-time sheet different from that at which the gravitational field of Earth resides. Alternatively, bio-systems could reduce the effective strength of Earth's gravitational force by channelling part of the gravitational flux of Earth to some other space-time sheet. Also classical Z^0 fields could contribute to the effective gravitational mass and gravitational force. This is suggested by the explanation of the acceleration anomaly of spacecrafts in outer space [K92]. It this is the case then similar mechanisms could be work for Z^0 electric flux too.

8.3.2 Particle Transfer And Re-Distribution Of Gauge Fluxes Between Space-Time Sheets As A Control Tool In Bio-Systems?

The basic mechanisms

Particle transfer between space-time sheets is the most straight-forward control mechanism. A more refined mechanism involves redistribution of various # contacts feeding gravitational and gauge fluxes to various space-time sheets from the space-time sheet of the particle.

1. In the transfer of particle between different space-time sheets topological sum contacts, "# throats", connecting the particle to space-time sheet are split and are possibly regenerated between particle and some other space-time sheet. All that it essential that particle disappears from a given space-time sheet. As a special case one has topological evaporation defined as a transfer of particles from a given space-time sheet to "vapor phase". This transfer process can be either classical or occur by quantum jump. The transfer of macroscopic particles by topological evaporation seems however very implausible. One reason for this is that the corresponding space-time sheet has large number wormhole contacts to a large number of space-time sheets and it is extremely improbable that these contacts can split simultaneously. Also the fact that the gravitational mass of particle in vapor phase vanishes, suggests strongly that evaporation process is possible only in elementary particle length scales.

2. It is also possible that temporary flux tubes between two space-time sheets, say atomic and cellular space-time sheets, are formed and particles flow from space-time sheet to another one along the flux tube. Join along boundary bonds could be formed both non-dissipatively (Josephson currents) or by quantum jumps giving rise to dissipative currents. For this process, which simply corresponds to the formation of direct geometric contact between physical objects, there is clear evidence from everyday life and the model for bio-control and -coordination relies on Josephson currents flowing between the space-time sheets. Josephson currents could give also rise to the "dropping" of electrons and ions from the atomic space-time sheet to larger space-time sheets. It seems that this mechanism might be the one which is realized in living matter. Also transfer of entire structures topologically condensed on given space-time sheet to a second space-time sheet is possibly along temporary flux tube formed between the two space-time sheets. This seems to happen all the time in everyday world: particle of even macroscopic size can diffuse from macroscopic objects to another one.

3. An interesting mechanism is the one in which # contacts of particle to a given space-time sheet glide to some other space-time sheet along flux tube. In this manner it would be possible to redistribute its own gravitational flux and gauge fluxes from original space-time sheet to some new space-time sheets. This would make possible for particle to reduce its effective gravitational mass. Also the gravitational force experienced by the particle would change as a result of this process: even levitation could become possible by transferring the # contacts to some nonstandard space-time sheet containing only very weak gravitational fields. This process is certainly possible: it requires only the formation of join along boundaries contact between the space-time sheet X at which particle usually feeds most of its gravitational flux and some other space-time sheet Y such that the contact can glide to Y without leaving particle space-time sheet.

Possible examples of particle transfer

Nondeterministic particle transfer between space-time sheets suggests a general mechanism for voluntary bio-control. For instance, particles could flow from atomic to cellular space-time sheets along join along boundaries bonds and particle transfer would be realized as dissipative em currents between the space-time sheets.

1. The transfer of individual electrons and Cooper pairs might provide an effective tool for the control of the electronic configuration of the cells and smaller structures. The concept of exotic atom involves dropping (presumably transfer along temporary flux tubes) of electrons from atomic space-time sheet to a larger space-time sheet and the electrons at almost empty space-time sheets could be in superconducting state. In these larger space-time sheets a very effective electronic charge transfer by supra currents could be possible since dissipative effects are minimized. One could even consider the possibility of a simultaneous coherent transfer of Cooper pairs at a given level of topological condensate. The transfer of particles along join along boundaries bonds/flux tubes formed between space-time sheets is the most plausible mechanism of a coherent transfer. The constructive interference of Josephson currents between space-time sheets could indeed induce large transfer of particles.

2. Ions and neutral atoms could "drop" from atomic to larger space-time sheets and form em of Z^0 superconductors at these space-time sheets. The macroscopic quantum phases formed by ions or their Cooper pairs are indeed in key role in TGD based models EEG and of sensory qualia.

3. The transfer of chemical reactants between space-times sheets provides a possible bio-chemical control mechanism. Again also the possibility of synchronous transfer induced by Josephson currents could be considered. One can consider the possibility that the transfer of most important organic molecules such as DNA sequences between space-time sheets is possible. This process provides an effective mechanism for controlling chemical reactions. For example, molecule could avoid Coulomb walls by moving on different space-time sheet and in case of a catalytic reactant this provides an effective control over the reaction. A new type of catalyst action becomes possible since catalyst molecule could overcome the purely geometric obstructions by moving on different space-time sheet ("Houdini effect") [K97]. The transfer of a molecule might be induced from $k = k_Z$ level. The motion of Z^0 # contacts in Z^0 fields at $k = k_Z$ level induces the motion of nuclei and therefore of molecule condensed on electromagnetic level $k_1 < k_Z$. If molecule enters the boundary of the condensate block k_1, it might suffer the transfer to a larger space-time sheet along join along boundaries bond.

Control mechanisms of motion

The transfer of particles between various space-time sheets suggests several mechanism for the control of locomotion.

1. As noticed, also macroscopic particles could flow between different space time sheets along join along boundaries bonds/flux tubes. The transfer of a substructure of cell size or even size of order 10^{-4} m could change the equilibrium configuration of the organ in external gravitational field. This kind of mechanism could provide a control tool for the motion of the organism.

2. Redistribution of the gravitational flux is made possible by the transfer of the ends of wormhole contacts along the join along boundaries bonds from standard space-time sheet to nonstandard ones. This makes it possible to change both the particle's effective gravitational mass and the effective gravitational field and could be involved with locomotion. This mechanism could explain the observed surprisingly large fluctuations in the value of the gravitational constant in Cavendish experiments [E1].

3. Much more tricky control mechanisms can be imagined. For instance, resonant current of Ca_{++} ions between atomic and cellular space-time sheets could induce oscillatory sol-gel transition in cytoplasm and this in turn would make possible amoeba like locomotion of a

monocellular organism in which organism becomes liquid in some direction and flows that direction and then solidifies. The frequency with which sol-gel transition occurs is few ten Hz and the transfer of Ca_{++} ions is known to be involved with its control. This suggests that resonant Ca_{++} ion currents with an odd multiple of Ca_{++} cyclotron frequency in Earth's magnetic field (15 Hz) are involved with the control of sol-gel transition. Bio-matter forms liquid crystals and sol-gel transition basically changes the liquid crystal characteristics such as the resistivity and the intensities of the spontaneously generated weak but coherent electric fields. In many-sheeted ionic flow equilibrium various (to be discussed in more detail in the sequel) ion densities at atomic space-time sheets are determined by the many-sheeted ionic flow equilibrium and are proportional k_{ion}/E, where k_{ion} denotes the ionic friction coefficient and E denotes the local electric field. It is quite possible that the transition to sol state is "let it go" type transition in which the electric drift velocity of the ion becomes so low that a stable control by super-conducting space-time sheets is not possible anymore.

Metabolism in the many-sheeted space-time and the real role of ATP

The dropping of ions from atomic space-time sheets to a much larger space-time sheet, say magnetic flux tubes of Earth's magnetic field or endogenous magnetic fields, liberates the large zero point kinetic energy associated with the particle at the atomic space-time sheet. p-Adic length scale hypothesis allows to estimate the precise value of the zero point energy. The assumption that the transformation of a single ATP molecule to ADP actually involves the dropping of a hydrogen ion from the atomic space-time sheet liberating .49 eV of zero point kinetic energy, allows to get rid of the questionable notion of high energy phosphate bond. ATP bound to magnesium atom couples the water cluster around ATP complex to the magnetic flux tubes and has thus control function rather than serving as a universal energy currency.

In many-sheeted space-time particles topologically condense at all space-time sheets having projection to given region of space-time so that this option makes sense only near the boundaries of space-time sheet of a given system. Also p-adic phase transition increasing the size of the space-time sheet could take place and the liberated energy would correspond to the reduction of zero point kinetic energy. Particles could be transferred from a portion of magnetic flux tube portion to another one with different value of magnetic field and possibly also of Planck constant h_{eff} so that cyclotron energy would be liberated. In the following only the "dropping" option is discussed.

The dropping of ions to high n magnetic cyclotron state decaying by the emission of ELF radiation at multiples of cyclotron frequencies provides a mechanism producing EEG. It is even possible to understand the value of the neuronal resting potential in terms of this mechanism. These applications are described in [K49].

The same mechanism explains also the scaling law of homeopathy stating that the imprinted frequencies in water appear in pairs of high and low frequencies implicating the presence of each other such that the ratio of the frequencies is $f_h/f_l = 2 \times 10^{11}$. This ratio can be identified as the ratio of the zero point kinetic energy of singly ionized ion at atomic space-time sheet to its cyclotron energy in Earth's magnetic field [K44].

8.3.3 Motor Control Performed By Field Body

As briefly described in the introduction, the notion of field body leads to the notion of magnetic sensory canvas [K54, K52]. Sensory representations are realized at the topological field quanta of Earth's magnetic field (flux tubes or shell like field quanta) and the magnetic flux tubes emanating from brain and body accompanied by parallel MEs serve as projectors to the magnetic sensory canvas. The distance of the object of perceptive field is coded by the thickness of the flux tube emanating from the brain in turn coding for the local cyclotron frequency scale.

This picture inspires questions about how the highest level motor control exercised by the field body is realized. Is motor control practiced directly from the magnetic sensory canvas or possibly from a separate Z^0 magnetic motor canvas? Second question relates to the mechanism of the motor control. In [K49] a mechanism of motor control based on Z^0 MEs converging to brain is discussed. The classical Z^0 fields could be transformed to endogenous sounds if the living matter acts as Z^0-piezoelectric. This is in principle possible since atomic nuclei can possess anomalous Z^0 charge and an entire hierarchy of scaled down weak physics possible corresponding to Gaussian

Mersennes $(1+i)^k - 1$, $k = 151, 157, 163, 167$ [K38] is possible. The control should be very high level control leaving a lot of freedom for brain to decide about the details. Perhaps internal speech is one manifestation of this control.

An important aspect of motor control is the generation of quantum entanglement: the geometric correlate for this is ME bridge. Only bound state entanglement is stable against the state preparation process associated with the quantum jump so that motor control is accompanied by the liberation of a binding energy as a usable energy. This obviously facilitates motor control. There is some evidence for the occurrence of the quantum metabolism. The regions of high neural activity in brain are not seats of high oxidative metabolism as one might expect and this has led to the puzzle about where the brain gets the energy it is believed to need [K49]. One possibility is that quantum metabolism provides the energy. Since thermal noise is expected to destroy the bound state entanglement sooner or later, one can say that thermal energy is utilized by buy now-pay later mechanism (there is definite analogy with thermal ratchets). During synesthesia left brain contains

oxidative metabolism is 18 per cent lower than normally: in case of a normal person this would mean death [K89]. Perhaps quantum metabolism explains also this anomaly.

8.3.4 Scaling Law Of Homeopathy And The Role Of Microwaves In Homeostasis

Plasmoids consisting of closed magnetic flux tube structures carrying supra currents plus atomic space-time sheets associated with them, are good candidates for primitive electromagnetic life forms. Ordinary bio-matter is assumed to self-organize around these structures and nerve circuit represents a good example of a structure resulting in this manner.

Also the magnetic life forms need energy feed to self-organize and stay awake. The basic metabolic mechanism would be the same as in the case of living matter [K49]. Energetic super-conducting ions must be somehow driven from the magnetic flux tubes to the atomic space-time sheets, where they collide with atoms, ionize them, and generate visible light in the atomic transitions giving thus rise to the observed luminous phenomena interpreted as UFOs. The ions would eventually "drop" back to the super-conducting space-time sheet and liberate the zero point kinetic energy as a quantum of metabolic energy defining what is often referred to as a universal energy currency. Essentially identical energetic cycle of Karma would be realized also in living matter but involve a complex molecular organization and many-sheeted current circuitry responsible for the control of homeostasis. For the proton the quantum is predicted to be of order .5 eV liberated also when a single molecule of ATP is used [K49].

The realization of this primitive metabolic cycle requires the breaking of super-conductivity: some mechanism must generate join along boundaries bonds serving as bridges connecting magnetic flux tubes with atomic space-time sheets along their boundaries so that supra current leakage becomes possible. The gap energy of super-conductors, typically measured in 10^{-4} eV as a unit (corresponding to temperature measured in Kelvins), would naturally correspond to the energy needed to build up this bond (note that the temperature at the magnetic flux tubes would be much lower).

This suggests that microwave photons could induce these bridges, break super-conductivity, and induce energy feed and self-organization. A similar breaking of super-conductivity might be also involved with the driving of the super-conducting ions to the atomic space-time sheets in the living matter. Proteins could generate the needed microwave photons by coherently occurring conformational transitions. Also rotational transitions of clusters of water molecules could emit microwaves and perhaps mimic and amplify the microwaves generated by proteins.

The clusters of water molecules forming liquid crystals can mimic the conformational and rotational spectrum of various molecules, and that the ability to reproduce the rotational frequency spectrum of the medicine molecule is an essential element of homeopathic healing. The level of self-organization of water would thus be measured by how complex mimicry it is able to perform.

Why rotational microwave energy spectrum is so important for healing, could be understood as follows. The many-sheeted current circuitry, involving atomic space-time sheets and magnetic flux tubes and also other space-time sheets, is extremely complex control structure. The continual regeneration of bridges between, say, atomic space-time sheets and magnetic flux tubes by microwaves emitted by proteins is necessary to sustain this circuitry. An important category of diseases is due to the failure to generate the bridges between super-conducting and atomic space-time sheets so that this control circuitry suffers shortcuts. Perhaps the genetic expression of some proteins responsible for the microwaves generating particular bridges fails. The medicine or its homeopathic counterpart would help to generate (or even re-establish the generation of) the microwave spectrum responsible for the generation of the lacking bridges in the circuitry.

A further piece to the puzzle comes from the scaling law of homeopathy. The law states that high and low frequencies accompany each other, the frequency ratio being $f_{high}/f_{low} \simeq 2 \times 10^{11}$ in the simplest situation (the ratio can actually vary). The TGD based interpretation is that ELF MEs are responsible for quantum entanglement in macroscopic, even astrophysical, length scales. Microwave MEs propagating effectively as mass-less particles along ELF MEs in turn induce self-organization by serving effectively as "food" of the plasmonic life forms at the receiving end. This mechanism could be behind both the endo- and exogenous realizations of intentions as actions, that is ordinary motor actions and phenomena like remote healing and psychokinesis. Also sensory representations at the personal magnetic canvas and magnetosphere rely on this mechanism, and in this case life forms are mental images getting at least partially their metabolic energy from brain.

As a matter fact, also other than microwaves photons, for instance IR and visible photons are predicted to be important for the self-organization of living matter but it seems that microwave photons are of special importance.

8.4 Quantum Tools For Bio-Control And -Coordination

Coordination and control are the two fundamental aspects in the functioning of the living matter. TGD suggests that at quantum level deterministic unitary time evolution of Dirac equation corresponds to coordination whereas time evolution by quantum jumps giving rise to self-organization corresponds to quantum control. The fractal hierarchies of MEs and super-conducting magnetic flux tubes and bio-matter at atomic space-time sheets would be the basic building blocks of the control system. The basic control structure would be many-sheeted ionic current circuitry: the currents would flow as supercurrents at magnetic flux tubes and as ohmic currents at atomic space-time sheets. MEs would interact with the super currents via magnetic induction and by forming Josephson junctions between magnetic flux tubes. An important mechanism of control would be "let it go" mechanism in which the control of atomic space-time sheets would fail for a moment: this would be like opening the faucet for a moment.

Supercurrents and non-dissipative Josephson currents associated with weakly coupled superconductors would be the key element in coordination whereas oscillating super currents and Josephson currents at resonance frequencies inducing quantum jumps and thus "waking-up" subselves and initiating quantum self-organization, would be crucial for control.

This view allows to consider more detailed mechanisms. What is certainly needed in the coordination of the grown-up organism are biological clocks, which are oscillators coupled to the biological activity of the organ. Good examples are the clocks coordinating the brain activity, respiration and heart beat [I81]. For example, in the heart beat the muscle contractions in various parts of heart occur in synchronized manner with a well defined phase differences. Various functional disorders, say heart fibrillation, result from the loss of this spatial coherence. For a control also biological alarm clocks are needed. An alarm clock is needed to tell when the time is ripe for the cell to replicate during morphogenesis. Some signal must tell that is time to begin differentiation to substructures during morphogenesis: for example, in case of the vertebrates the generation of somites is a very regular process starting at certain phase of development and proceeding with a clockwise precision.

8.4.1 Many-Sheeted Ionic Flow Equilibrium As A Fundamental Control Mechanism

Many-sheeted ionic flow equilibrium in which supra currents at magnetic flux tubes flow to atomic space-time sheets where they run as ohmic currents, and back, is very attractive quantum control mechanism and the empirical facts discussed in the [K21, K22] provide strong support for this mechanism.

1. The mechanism requires the presence of coherent electric fields at atomic space-time sheets, which can however be very weak. The liquid crystal property implying electret property guarantees this. Current conservation relates the ionic densities in super-conducting magnetic flux tube circuitry and non-super-conducting atomic parts of the circuitry. For the simplest circuit one has in equilibrium $I_{super} = n_{super}v_{super} = I_{atom} = n_{atom}v_{atom}$, which gives

$$n_{atom} = n_{super} \times \frac{v_{super}}{v_{atom}} .$$

The atomic drift velocity v_{atom} relates to the electric field E at the atomic space-time sheet and to the coefficient k_{ion} characterizing the proportionality of the ionic friction force to velocity

$$v_{atom} = \frac{E}{k_{ion}} .$$

The weaker the electric field and the stronger the ionic friction, the stronger the amplification of the super-conducting ionic density to the ionic density at atomic space-time sheet is. Therefore very weak super-conducting ion densities can perform effective control.

2. v_{super} is typically proportional to the magnetic quantum number characterizing super current and the interaction of the current circuits with the external magnetic fields, in particular those associated with MEs, can change the value of the super-conducting ionic velocity v_{super} (magnetic flux is related to current via $\Phi = LI$ modulo elementary flux quantum). This means that MEs can control the densities of the ions at atomic space-time sheets. If the electric field and friction coefficient remain constant paramaters, the values of the ion densities at atomic space-time sheets are quantized by the quantization of the magnetic quantum number, typically integer. This might provide an empirical test for the mechanism.

3. The rates for the quantum transitions for Bose-Einstein condensates of super-conducting ions are proportional to N^2, where N is the number of ions. This means coherence and amplification. This could in fact lead to quantum phase transitions in which all ions experience the same quantum transition. In particular, magnetic quantum phase transitions suggest itself and they could make possible what might be called endogenous nuclear magnetic resonance (NMR) spectroscopy: the generated coherent light would Bose-Einstein condense on MEs and generate conscious experience and give rise to chemical qualia. Perhaps even other than magnetic quantum phase transitions could occur. One cannot exclude the possibility that even DNA and proteins could form super-conducting BE condensates (although the large number of internal almost degenerate states perhaps hinders this) and MEs could thus control their conformations by inducing conformation changing transitions. This would make possible very effective bio-control by controlling the conformations of enzyme molecules determining their catalytic properties.

4. By their small mass implying high mobility, electrons play an important role in the control of the conformations of bio-molecules. Electronic flow equilibrium between molecular and atomic space-time sheets could be responsible for the quantum control of the molecular conformations. The electronic supra-currents associated with DNA and protein space-time sheets could be directly controlled by the interaction with MEs; the supra-currents (depending on magnetic quantum numbers) would in control the distribution of electrons at the atomic space-time sheets, which in turn would determine the conformation of the bio-molecule. MEs could thus induce collective phase transitions between various molecular conformations. This mechanism seems more plausible than the participancy of large bio-molecules to the many-sheeted ionic flow.

   Immune system would guarantee that the frequencies associated with the transitions inducing changes of all protein and DNA conformations so near to each other so that MEs can induce these collective phase transitions efficiently. For not quite identical invader proteins these frequencies are too different and they cannot participate to the coherent phase transitions. The recognition of the invader proteins could be based on the very fact that they do not respond to the same frequencies as the own proteins of the organism.

8.4.2 Self-Hierarchy And Hierarchy Of Weakly Coupled Superconductors

The realization that bio-systems are full of macroscopic quantum phases led to the general idea about the dynamical realization of the self-hierarchy as a master-slave hierarchy formed by weakly coupled superconductors. The formation of flux tubes between the space-time sheets at different levels of the self hierarchy makes it possible for a higher level self, not only to experience what it is to be the lower level self, but also to perform quantum control. Join along boundaries bonds give rise to Josephson junctions carrying Josephson current characterized by Josephson frequency.

The first proposal for the mechanism of bio-control was based on the idea was that when Josephson frequency equals to the energy difference of the quantum states of the charge carriers localized in either superconductor, resonant transfer of ions between superconductors occurs. If the localized states in question result from magnetic confinement, energy difference corresponds to a multiple of the cyclotron frequency of the charge carrier. Also supra currents and ohmic currents (above critical flow velocity) could flow through the flux tubes and are expected to be also important in bio-control. The later work did not lead to any detailed realization of this model and led to proposal for a model of quantum bio-control which makes sense only in the full conceptual framework provided by TGD.

The observed effects of various ELF fields on brain can be indeed understood if cyclotron frequencies in an endogenous magnetic field $B_{end} = .2$ Gauss are in question. This magnetic field is not equal to the magnetic field of Earth as I erratically believed for a long time but relates to the nominal value $B_E = .5$ Gauss of the Earth's magnetic field by the scaling $B_{end} = 2B_E/5$. The interpretation of B_{end} as a dark counterpart of the Earth's magnetic field carrying dark ionic Bose-Einstein condensates turns out to be natural in TGD framework.

This leads to a beautiful general realization of quantum control. Destructive interference of supra currents leads to a large net Josephson current and various biological clocks could rely on this mechanism. When reference supra current representing the expected sensory input and a current representing real sensory input and flowing in parallel manner in weakly coupled superconductors, are sufficiently near to each other, constructive interference of the Josephson currents occurs and can give rise to a synchronous firing. This makes possible conscious comparison circuits. Conscious novelty detectors can be build easily from comparison circuits using inhibitory and excitatory synaptic connections.

Simple model for weakly coupled super conductors

Several kinds of Josephson currents between cell interior and exterior are possible. Soliton sequences are the simplest solutions of Sine-Gordon equation for the Josephson junctions associated with a linear structure such as axon idealized as an infinitely long and thin cylindrical surface and are mathematically equivalent with a rotating gravitational pendulum.

The most general formulation starts from the Klein-Gordon equation for the order parameters Ψ_i, $i = 1, 2$ for the super-conductors coupled linearly to each other in the junction

$$\begin{aligned} D\Psi_1 &= m^2\Psi_1 + m_{12}^2\Psi_2 \ , \\ D\Psi_2 &= m^2\Psi_2 + m_{12}^2\Psi_1 \ , \\ D &= (\partial_\mu + iZeA_\mu)(\partial_\mu - iZeA_\mu) \end{aligned} \tag{8.4.1}$$

Here m denotes the charge of the super-conducting particle (say Cooper pair) and m_{12}^2 is real parameter characterizing the coupling between the superconductors. A_μ denotes electromagnetic vector potential associated with the superconductors.

Weakly coupled superconductors are assumed to possess cylindrical symmetry and can regarded as inner and out cylinder with Josephson junctions idealized with smooth distribution of them. If ME acts as Josephson junctions this assumption is exact. Weak coupling means that that the densities of charge carriers are same at the two sides of the junction in a good approximation:

$$\Psi_i = \sqrt{n} exp(i\Phi_i) \ , \ i = 1, 2 \ . \tag{8.4.2}$$

Under these assumptions one obtains for the phase difference $\Phi \equiv \Phi_1 - \Phi_2$ the Sine-Gordon equation with a coupling to the vector potential

$$\partial^\mu \left[\partial_\mu \Phi - q\Delta A_\mu\right] = m_{12}^2 sin(\Phi) \tag{8.4.3}$$

ΔA_μ denotes the difference of the vector potential over the junction. q denotes the charge of the super-conducting charge carrier.

Note that Lorentz gauge condition

$$\partial_\mu A^\mu = 0 \tag{8.4.4}$$

does not trivialize the coupling to the vector potential since the equation holds true only in 3-dimensional surface defining the junction and the contribution from the direction of the normal is not present.

Josephson current J_J can be identified as the divergence of the 4-current $j_\mu = Ze\rho = Ze\Psi^*(\partial_\mu^{\rightarrow} - \partial_\mu^{\leftarrow})\Psi$ at the either side of the junction.

$$J_J = \partial_\mu J^\mu = Ze \times \frac{n}{m} \times m_{12}^2 sin(\Phi) \ . \tag{8.4.5}$$

The Josephson current per unit length of axonal membrane of radius R and thickness d is given by

$$J = Ze \times \frac{n 2\pi R d}{m} \times m_{12}^2 sin(\Phi) \ . \tag{8.4.6}$$

The parameter m_{12}^2 is analogous to the inverse of the magnetic penetration length squared ($\hbar = c = 1$) for the super-conductors involved.

$$m_{12}^2 = \frac{1}{\Lambda^2} \ . \tag{8.4.7}$$

If one can regard the Josephson junction region as a defect in a super-conductor, Λ is apart from a numerical constant of order unity equal to the thickness of the Josephson junction. In the case of the cell membrane this would mean that the small oscillations associated with the Josephson junction have frequencies of order 10^{16} Hz and correspond to quanta with energies of order 100 eV.

The covariant constancy conditions

$$\begin{aligned} \partial_t \Phi &= ZeV(t,z) \ , \\ \partial_z \Phi &= ZeA_z(t,z) \ . \end{aligned} \tag{8.4.8}$$

are mutually consistent only if the electric field in the axial direction vanishes. They are not however consistent with the right hand side of the equation and only one of the conditions can be satisfied. The condition effectively reduces the equation to an ordinary differential equation. Of course, one cannot assume the condition for general solutions.

For a constant potential difference V_0 the Josephson current is sinusoidal for $\partial_t \Phi = ZeV_0$ ansatz with the basic frequency given by $\omega = eV_0$. An exact treatment replaces the sinusoidal time dependence of Φ with the time dependence of the angle coordinate of gravitational pendulum so that higher harmonics are involved. In case of cell membrane $V(t)$ is typically a sum of constant part and time dependent part giving rise to frequency modulation of the basic Josephson current:

$$\omega(t) = eV = eV_0 + eV_1(t) \ .$$

Entire hierarchy of frequency modulations is possible since also eV_1 can be frequency modulated by Josephson currents.

Josephson junctions and interaction with coherent photons

Josephson junctions between two electronic super conductors make possible the coupling of super conductors to coherent photons, which in TGD based biology are emitted by various linear structures (in case that these structures contain space-time sheet representing massless extremals). The macroscopic description of Josephson junction is based on the current-voltage relation [D59, D24]

$$\begin{aligned} I &= I_0 sin(\phi) + C_j\frac{dV}{dt} + \frac{V}{R_j} \ , \\ \phi &= \int 2eVdt \ . \end{aligned} \tag{8.4.9}$$

Critical current I_0, the shunt resistance R_j and the capacitance C_j are macroscopic parameters in the description of the Josephson junction. Note that C_j is essentially kinematical parameter determined by the geometry of the Josephson junction. ϕ is equal to phase difference between the weakly coupled superconductors and $I_0 sin(\phi)$ is the Josephson current giving rise to the typical stepwise current-voltage characteristic. I_0 can be related to the microscopic properties of the Josephson junction.

A good candidate for a Josephson junction is cell membrane. In this case Josephson current corresponds to a protein connecting the lipid layers of the cell membrane. If Cooper pairs tunnel, I_0 is proportional to density of Cooper pairs at space-time sheet involved and to the rate for the tunnelling of single Cooper pair. If single electron tunnelling is in question, I_0 is proportional to the rate of single electron tunnelling and the density of the unpaired electrons. It is in principle quite possible to estimate I_0 for, say, proteins connecting cell membrane.

In case that there are several parallel Josephson junctions the current contains sum over various Josephson currents and destructive interference between the Josephson currents becomes possible. Quantum criticality suggests that destructive interference might serve as a biological alarm clock based on the interference of some reference current and a current describing input to system and representing perhaps sensory data. Dissipation would lead to the reduction of the reference current but the ringing of the clock induced in this manner would regenerate the reference current automatically. Second possibility is a comparison circuit based on parallel supra currents of equal magnitude flowing in weakly coupled super conductors. If the currents are in the same phase, constructive interference of Josephson currents associated with various Josephson junctions occurs and can in turn lead to large effects, such as neural firing.

Josephson junctions can be realized as flux tubes and the potential difference between the coupled superconductors characterizes the link as far as the electromagnetic coupling is considered: the energies of photons emitted by the Josephson current are multiples of the potential difference eV: $E = neV$ [D59, D24]. For cell membrane eV is about $eV \simeq .05$ eV.

Simplest solutions of Sine-Gordon equation

Free Sine-Gordon equation resulting, when the coupling to the em field can be neglected, gives a good view about the solutions of full equation. In cylindrical geometry Sine-Gordon equation becomes effectively 2-dimensional under rather natural conditions. This is rather nice since two-dimensional Sine-Gordon equation is completely integrable and thus allows an infinite number of conserved charges [B5].

Sine-Gordon equation allows two kinds of vacua. The vacua of first type correspond to $\Phi = 2n\pi$ ground state configuration and vacua second type to $\Phi = (2n+1)\pi$. The small perturbations around these vacua correspond to massive 1+2 dimensional free field theory with field equations

$$\begin{aligned} D\Phi &= \epsilon\frac{1}{\Lambda^2}\Phi \ ; \\ D &= \partial_t^2 - \nabla^2 \ , \\ \epsilon &= -1 \ \text{for} \ \Phi = n2\pi \ , \\ \epsilon &= 1 \ \text{for} \ \Phi = (2n+1)\pi \ . \end{aligned} \tag{8.4.10}$$

In the language of quantum field theory, the small perturbations around $\Phi = n2\pi$ describe particle with mass squared $m^2 = \frac{1}{\Lambda^2}$ whereas the small perturbations of the $\Phi = (2n+1)\pi$ vacuum describe tachyons with negative mass squared $m^2 = -\frac{1}{\Lambda^2}$. Therefore these vacua will be referred to as time like and space like respectively.

One might argue that the space like vacua are unstable in the case that the continuous sheet of the Josephson junctions consists actually of discrete Josephson junctions, whose dynamics is given by the differential equation

$$\frac{d^2\Phi}{dt^2} = -\frac{sin(\Phi)}{\Lambda^2}$$

allowing only $\Phi = n2\pi$ as stable ground state. For MEs acting as Josephson junction the situation is different. On the other hand, the ground state at which soliton generation is possible should be quantum critical and hence very sensitive to external perturbations. Note that time like and space like sectors in axonal portion of neuron are permuted by a duality transformation $z \leftrightarrow vt$ (v=c=1), $\Phi \rightarrow \Phi + \pi$, which is exact symmetry of the 1+1-dimensional Sine-Gordon equation.

The propagating waves are of form $sin(u)$, where one has

$$\begin{aligned}
u &= \gamma_P(t - \frac{v_P z}{v^2}) \ , \ \text{time like case} \\
u &= \gamma_P(z - v_P t) \ , \ \text{space like case} \\
\gamma_P &= \sqrt{\frac{1}{1 - (\frac{v_P}{v})^2}} \ .
\end{aligned} \tag{8.4.11}$$

Here v_P is the velocity parameter characterizing the boost. The frequency of these small propagating oscillations (plane waves) is in two cases given by

$$\begin{aligned}
\Omega &= \frac{\gamma_P v}{\Lambda} \ , \ \text{time like case} \ , \\
\Omega &= \frac{\gamma_P v_P}{\Lambda} \ , \ \text{space like case} \ .
\end{aligned} \tag{8.4.12}$$

The frequency is very high for time like waves, of order 10^{10} Hz and therefore a typical time scale for the conformational dynamics of proteins. In space like case the phase velocity of the propagating waves is $v_P < v$ and frequencies are small and one could consider the possibility of identifying these oscillations as propagating EEG waves. For the time like excitations phase velocity is $v_p = v^2/v_P > v$ and larger than light velocity. For ordinary elementary particles the situation is same but since phase velocity is in question, there are no interpretational problems.

One-dimensional solutions of the Sine-Gordon equation give quite satisfactory picture about the situation as far as the physical interpretation is considered. The simplest solutions of this type correspond to solutions depending on time or spatial coordinates only. For time like vacua one-dimensional solutions depend on time only: note that these solutions are possible for arbitrary geometry of the Josephson junction. For space like like vacua one-dimensional solutions are possible in the axonal portions of the neuron: the simplest one-dimensional solutions depend on the axonal coordinate z only.

Field equations reduce to the equations of motion for gravitational pendulum:

$$\frac{d^2\Phi}{du^2} = -\frac{1}{\Lambda^2}sin(\Phi) \ . \tag{8.4.13}$$

$u = vt$ holds true in time like case ($v = c \equiv 1$ is good approximation). $u = z$ holds true in space like case (in this case equation makes sense for axonal portions only). Energy conservation for the gravitational pendulum gives

$$\frac{1}{2}v^2(\frac{d\Phi}{du})^2 + \frac{v^2}{\Lambda^2}\left[1 - cos(\Phi)\right] = K\frac{2v^2}{\Lambda^2} \ , \tag{8.4.14}$$

where K is dimensionless constant analogous to energy. There are two kinds of solutions: oscillating solutions ($K < 1$) and rotating solutions ($K > 1$): single soliton solution corresponds to $K = 1$.

One can integrate the conservation law for energy to give the time/spatial period of oscillation or rotation (T/λ). For oscillating solutions one has

$$T = \frac{\lambda}{v} = \frac{\Lambda}{v}\int_{-\Phi_0}^{+\Phi_0} d\Phi \frac{1}{\sqrt{2\left[-cos(\Phi_0) + cos(\Phi)\right]}} . \tag{8.4.15}$$

Here Φ_0 is maximum value of the phase angle for oscillating solution. For the rotation period one obtains

$$T = \frac{\lambda}{v} = \frac{\Lambda}{v}\int_{0}^{2\pi} d\Phi \frac{1}{\sqrt{(\frac{d\Phi}{dt})^2(\Phi = \pi) + 2\left[1 - cos(\Phi)\right]}} . \tag{8.4.16}$$

By Lorentz-boosting space like axonal solutions to move with velocity v_p one obtains propagating soliton sequences.

Sine-Gordon equation is completely integrable and thus allows an infinite number of conserved charges. In quantum theory the eigenvalues of mutually commuting charges characterize the quantum state and these charges are basic quantum observables. Does it make sense to quantize Sine-Gordon and could one characterize the state of the axonal membrane in terms of these charges? Here one must point out the similarity to the ideas of [J28] [J28], who speculates with the possibility that certain 2-dimensional conformal field theory characterizes the state of micro-tubule and the infinite number of conserve charges characterize the information content of the micro-tubule. It is perhaps also worth of mentioning that the quantum group $SU(2)$ appears in the quantization of the Sine-Gordon equation [B26]: could quantum groups have important applications in biology?

Modulation hierarchy of Josephson currents

The modulation of the Josephson current is induced by the oscillatory time varying part of the potential difference superposed to constant part. The oscillatory time dependent part can be generated by an oscillatory em current through the cell membrane or running from cellular space-time sheet to some other space-time sheet via join along boundaries bonds. Also currents which run between different levels of the p-adic lengths scale hierarchy and could flow along join along boundaries bonds connecting space-time sheets at different levels of the hierarchy.

One can consider also frequency modulations of frequency modulations of.... forming a hierarchical structure analogous to the abstraction hierarchy and giving rise to abstraction hierarchy of senses. This would explain the effects of various frequency modulated signals to brain. The effects of external em field to bio-system are expected to be largest when the frequency modulated signal is as nearly as possible equal to the modulating part of the membrane potential. Modulation hierarchy can be realized if the em current yielding modulation at given level is itself Josephson current so that entire hierarchy of Josephson junctions is implied. In this case modulating current cannot be between cell interior and exterior however but between cell interior or interior and some other space-time sheet at same or different p-adic hierarchy level. Josephson currents induce oscillatory changes of total charges of space-time sheets involved and these in turn induce oscillatory modulations of the potential differences between various Josephson junctions.

The hypothesis that modulation hierarchy corresponds to the p-adic hierarchy of space-time sheets suggests that Josephson currents in question are between space-time sheet representing different hierarchy levels. Josephson current flow along the join along boundary contacts connecting these space-time sheets ("biofeedback"). The current would change the density of charged particles at cellular space-time sheet and induce change of the membrane potential proportional to the Josephson current in question. An essential point is that the two space-time sheets in question ought to be superconducting.

8.4.3 General Mechanism Making PossibleBiological Clocks And Alarm Clocks, Comparison Circuits And Novelty Detectors

Weakly coupled superconductors and quantum self-organization make possible very general models of biological clocks and alarm clocks as well as comparison circuits and novelty detectors.

The Josephson junction between two super-conductors provides a way to realize a biological clock. Josephson current can be written in the form [D59]

$$\begin{aligned} J &= J_0 sin(\Delta\Phi) = J_0 sin(\Omega t) \ , \\ \Omega &= ZeV \ , \end{aligned} \tag{8.4.17}$$

where Ω is proportional to the potential difference over the Josephson junction. Josephson current flows without dissipation.

In BCS theory of super-conductivity the value of the current J_0 can be expressed in terms of the energy gap Δ of the superconductor and the ordinary conductivity of the junction. When the temperature is much smaller than critical temperature, the current density for a junction is given by the expression [D59]

$$J_0 = \frac{\pi}{2e}\frac{\sigma_s\Delta}{d} \ . \tag{8.4.18}$$

Here σ_s is the conductivity of the junction in the normal state assuming that all conduction electrons can become carriers of the supra current. d is the distance between the superconductors. The current in turn implies a position independent(!) oscillation of the Cooper pair density inside the two superconductors. By the previous arguments the density of the Cooper pairs is an ideal tool of bio-control and a rhythmic change in biological activity expected to result in general. Josephson junctions are therefore good candidates for pacemakers not only in brain but also in heart and in respiratory system.

In the presence of several parallel Josephson junctions quantum interference effects become possible if supra currents flow in the super conductors. Supra current is proportional to the gradient of the phase angle associated with the order parameter, so that the phase angle Φ is not same for the Josephson junctions anymore and the total Josephson current reads as

$$J = \sum_n J_0(n) sin(\Omega t + \Delta\Phi(n)) \ . \tag{8.4.19}$$

It is clear that destructive interference takes place. The degree of the destructive interference depends on the magnitude of the supra currents and on the number of Josephson junctions.

There are several options depending on whether both superconductors carry parallel supra currents or whether only second superconductor carries supra current.

1. If both superconductors carry supra currents of same magnitude but different velocity, the phases associated with the currents have different spatial dependence and destructive interference occurs unless the currents propagate with similar velocity. This mechanism makes possible comparison circuit serving as a feature detector. What is needed is to represent the feature to be detected by a fixed supra current in the second superconductor and the input as supra current with same charge density but difference velocity. The problem is how the system is able to generate and preserve the reference current. If case that feature detector "wakes-up" into self state when feature detection occurs, the subsequent quantum self-organization should lead to the generation of the reference current representing the feature to be detected.

2. If only second superconductor carries supra current and of this supra current for some reason decreases or becomes zero, constructive interference occurs for individual Josephson currents and net Josephson current increases: current causes large gradients of Cooper pair density and can lead to the in-stability of the structure. When the supra current in the circuit

dissipates below a critical value, in-stability emerges. This provides a general mechanism of biological alarm clock.

Assume that the second superconductor carriers a supra current. As the time passes the reference current dissipates by phase slippages [D56, D59]. If the reference current is large enough, the dissipation takes place with a constant rate. This in turn means that the Josephson current increases in the course of time. When the amplitude of the Josephson current becomes large enough, the density gradients of the charge carriers implied by it lead to an instability of the controlled system: the clock rings. Since the dissipation of (a sufficiently large) Josephson current takes place at constant rate this alarm clock can be quite accurate. It will be found that a variant of this mechanism might be at work even in the replication of DNA. The in-stability itself can regenerate the reference current to the clock. If the alarm clock actually "wakes-up" the alarm clock to self state, self-organization by quantum jumps must lead to an asymptotic self-organization pattern in which the supra current in the circuit is the original one. Actually this should occur since asymptotic self-organization pattern depends only weakly on the initial values.

3. Novelty detector can be build by feeding the outputs of the feature detectors to an alarm clock circuit. In alarm clock circuit only the second superconductor carries supra current, which represents the sum of the outputs of the feature detectors. Since the output of a feature detector is non-vanishing only provided the input corresponds to the feature to be detected, the Josephson current in additional circuit becomes large only when the input does not correspond to any familiar pattern.

8.4.4 Biological Quantum Control Circuits

Various macroscopic quantum phases such as the BE condensate of # contacts, electronic and ionic Cooper pairs, ions and even neutrino Cooper pairs and atomic Cooper pairs forming Z^0 super conductors provide a rich repertoire of possible realizations for comparison circuits, biological clock and alarm clocks as well as feature- and novelty detectors. Note that # contacts are expected to appear in all biologically relevant length scales.

1. Biological clock consists of parallel Josephson junctions between two subsystems, which could be organs or organelles or even bio-molecules. There is a sinusoidally varying Josephson current between the two super-conductors in question. Note that also propagating waves are possible. For the ordinary electronic superconductor, the current for a single junction is given by $J \propto (\Delta\sigma/\Omega)sin(\Omega t)$. The value of the conductivity σ depends on the properties of the Josephson junction. It is rather remarkable, that for low frequencies Ω the current increases: this could correlate with the fact that low frequency EEG amplitudes are larger than high frequency amplitudes if EEG frequencies indeed correspond to Josephson frequencies for ionic Josephson currents.

2. Possible biological applications are feature- and novelty detection in brain: very complicated logical circuits waking up some sub-self under given conditions are possible and can give rise to complicated program like behaviors in which wake-up leads to self-organization process. Simpler applications are clocks and alarm clocks with brain (EEG and wake-up cycle) and heart beat and respiratory system. The additional bonus of the Josephson clock is that the nerve pulses generating the muscle contraction in the heart beat and respiration cycle can be generated at the second half of the clock period only so that very sharp control is achieved. These examples suggests that Ω is very small in general. There exist direct evidence for the Josephson clock at the muscle level: the rest length of the muscle is known to oscillate with a frequency of about 50 Hz. Josephson clock implies a periodic variation of the density of the charge carriers inside the muscle and the sensitivity of the stable length of the muscle to the density of the charge carriers implies the oscillatory behavior of the muscle length, too. Oscillation could directly relate with the oscillation of the muscle cell resting potential with this frequency such that nerve pulses are generated when resting potential is near to its minimum.

3. The spatial dependence of the order parameter provides a tool for the spatial synchronization. The large scale variations constant in the length scale of an individual biological alarm clock imply that the clocks have nonrandom lag with respect to some reference clock. This means that the process started by the ringing of the clocks propagates in an orderly fashion. As far as morphogenesis is considered, the really nice feature of the alarm clock mechanism is that the only information stored is the time lapse to the ringing of the clock and this can be stored, when the clock is created rather than being stored in the DNA of the organism. The same can be said about the phase information needed for a spatial synchronization. What happens is the feeding of negentropy to the clock from the environment, when the reference current is generated.

4. Binary structures are very general in bio-systems and seem to be associated with pairs of p-adic primes whose p-adic length scales are related by a factor of two. There are amazingly very many of them in the p-adic length scale range relevant to bio-systems (DNA double helices, cell membranes, epithelial sheets, bi-layered structures of cortex). Typically these structures consist of a large number of smaller subunits (lipids in case of lipid layers of cell membrane, cells in case of the epithelial sheet, larger groups of cells in case of structures of cortex). These structures are optimal comparison circuits and thus also feature- and novelty detectors as well as clocks and alarm clocks. What is needed is that the components of the bilayered structure are weakly coupled superconductors of some kind.

8.4.5 A Quantitative Model For The Bio-Control Performed By # Contact Be Condensate

Since # contacts are expected to form BE condensates at all space-time sheets of the topological condensate, they provide an ideal tool for the control and coordination in bio-systems. If bio-systems correspond to 4-surfaces, which are small deformations of the vacuum extremals of Kähler action, the idea about # contacts as the master and the geometry and 3-topology as slave is very attractive. For the coordination biological clocks are need. # contact BE condensate is very much like superconductor and Josephson junctions with an oscillating phase difference as well as propagating waves are possible. For bio-control localized kinks, solitons, representing a localized increment of the phase angle Ψ or Φ by a multiple of 2π could be crucial. These kinks should be created by a process analogous to the phase slippage process.

It is highly desirable to find a quantitative formulation for the coupling between # contact BE condensate and 3-geometry in terms of a variational principle. This kind of formulation is indeed possible and is obtained from the free action associated with the # contact condensate by writing it in the induced metric for the boundary of the space-time surface regarded as a dynamical object.

Formulation of the model

The physical constraints on the action are as follows:

1. The field equations for the # contact order parameter describe charged bosonic particles with mass m of order $m \sim 1/L(n)$, where $L(n)$ is the characteristics length scale associated with the condensate level n. This amounts to the addition of a term of form

$$L_0 = \bar{\psi}(-D^\mu D_\mu - m^2)\psi\sqrt{g} \ , \tag{8.4.20}$$

to the action. Here D_μ is the covariant derivative in the induced metric including also the term giving coupling to the difference of the classical electromagnetic gauge potentials associated with the two space-time sheets involved. If coherent photons are present, a similar term associated with the topologically condensed coherent photons on the two space-time sheets, is present. Index raising is performed using the induced metric regarded as a dynamical variable.

2. The total electromagnetic charge of the 3-surface is fixed, so that the total charge associated with the BE condensate is $N(\#)$ and is conserved. This condition is included as a Lagrange multiplier term

$$S_1 = \int dt\lambda_1(t)\left[\int \bar{\psi}(i\partial_t^{\leftarrow} - i\partial_t^{\rightarrow})\psi\sqrt{g_2}d^2x - N(\#)\right] . \tag{8.4.21}$$

The term breaks manifest coordinate invariance.

3. At least in the length scales sufficiently larger than molecular length scales, the volume of the 3-surface can be assumed to be fixed since hydrodynamic flow is incompressible in excellent approximation. This amounts to the addition of a Lagrange multiplier term

$$S_2 = \int dt\lambda_2(t)\left[\int \sqrt{g_3}d^3x - V\right] . \tag{8.4.22}$$

This term gives rise to a term appearing as a source term in the equations determining the geometric form of the boundary of the 3-surface.

4. The intuitive expectation # contact BE condensate can exist in two phases analogous to superconductor of type I and II respectively. In the first phase the surface area is minimized and the density of the # contacts is maximized. This phases clearly corresponds to the situation in which the 3-surface is far from a vacuum extremal. In the second phase the surface area is maximized and the density of the # contacts is minimized. This phase corresponds to the 3-surface near to a vacuum extremal and the generation of regions of this phase can lead to the changes of the molecular conformations and to the changes of the macroscopic shape of the organ. The presence of the two phases is achieved by adding a "mass renormalization term"

$$\begin{aligned} L_\Delta &= \Delta m^2 n\sqrt{g} \ , \\ n &\equiv \bar{\psi}\psi \ . \end{aligned} \tag{8.4.23}$$

to the action and taking care that the # contacts propagate with a correct mass by using a Lagrange multiplier:

$$L_3 = \lambda_3 L_0 \ . \tag{8.4.24}$$

Δm^2 could also have a slow dependence on position.

5. The sign of Δm^2 determines the character of the system. If the sign is positive/negative the surface energy density is negative and surface area is minimized/maximized. Thus Δm^2 could serve as a control parameter, whose changes induce changes in the conformation of the 3-surface. The value of Δm^2 could be taken as input and could depend on parameter such as temperature and electromagnetic potential differences. One can imagine the existence of a critical temperature T_c such that $\Delta m^2 \propto T_c - T$ holds true. In low temperatures the 3-surface would freeze and minimizes the area of its outer boundary. In high temperatures 3-surface would become fractal like and random.

6. The maximization of the surface area with a fixed volume leads to an in-stability since a surface with a given volume can have an arbitrarily large surface area. This suggests that Δm^2 term contains also a regulating term nonlinear in ψ. In the spirit of Ginzburg-Landau action, one could have

$$\begin{aligned} L_{\Delta_1} &= \Delta_1 m^2 n\sqrt{g} \ , \\ \Delta_1 m^2 &= \lambda(n-n_0) \ , \\ n &\equiv \bar{\psi}\psi \ . \end{aligned} \tag{8.4.25}$$

The most reasonable choice for the sign of the term is dictated by the stability requirement. Below the critical value n_0 of the # contact density the 3-surface should be minimized (, which increases n) its area whereas above n_0 the area should be maximized (, which reduces n). This term need not appear in the wave equation as usually, if the constraint term gives wave equation. It however appears in the energy density and the ground state solution can be fixed by requiring the minimization of the energy.

Field equations

With these assumptions the field equations reduce to the wave equation for the order parameter in the induced metric

$$(-D^{\mu}D_{\mu} - m^2)\psi = 0 \ , \tag{8.4.26}$$

and to equations analogous to the conservation of the energy momentum associated with the order parameter:

$$\begin{aligned} D_{\beta}(T^{\alpha\beta}\partial_{\beta}h^k) &= \lambda_1 g_3^{n\beta}\partial_{\beta}h^k + ... \ , \\ T_{\alpha\beta} &= \bar{\psi}D_{\alpha}^{\leftarrow}D_{\beta}\psi - \frac{1}{4}g_{\alpha\beta}L_0 \ . \end{aligned} \tag{8.4.27}$$

The source term comes from the volume constraint. There are analogous source terms associated with the other constraints. These terms are present only provided the corresponding Lagrange multipliers are non-vanishing.

Neglecting the presence of the gauge potential terms, possibly not transformable away by a gauge transformation, the simplest stationary solution of the equations is of the form

$$\begin{aligned} \psi &= exp(imt)\psi_0 \ , \\ n = \bar{\psi}_0\psi_0 &= \frac{N(\#)}{mA} \ , \end{aligned} \tag{8.4.28}$$

where A is the total surface area. The terms involving time derivatives disappear from the field equations determining the 3-surface and if Δm^2 is non-vanishing the field equations reduce to the condition stating that the 3-surface minimizes/maximizes its surface area subject to the condition that its volume is fixed. In the critical case with $\Delta m^2 = 0$ the equations state nothing about the form of the boundary surface and it becomes completely random (but static) at criticality.

8.4.6 Model For Weakly Coupled Wormhole Superconductors

Wormhole superconductivity played a key role in earlier quantum model for EEG and nerve pulse. Although it turned out that the proposed role is very probably not realized in real world, weakly coupled wormhole superconductors are quite possible and there is even evidence for them. The hypothesis that potential differences associated with various Josephson junctions correspond to cyclotron frequencies, suggests that cell interior and exterior should form pair of weakly coupled wormhole superconductors such that the wormholes contacts in question connect $k = 169$ cellular space-time sheet and $k = 173$ space-time sheet at the next level of the hierarchy. The time scale associated with this particular wormhole superconductivity is obviously quite different from that associated with nerve pulse generation and EEG and the time scale in which possible quantum control takes corresponds to the natural time scale for molecular vibrational levels (photon energies in near infrared). In the following model for the Josephson junction of wormhole superconductors assumes for definiteness that lipid layers of the cell membrane are the coupled superconductors: reader can easily generalize the results to more general case.

Physical picture

The effective charge carriers are # contacts feeding em charge between two space-time sheets. There are actually opposite classical em currents at the two space-time sheets and in quantum field context there is just the current of extremely tiny Planck length scale dipoles having practically no coupling to photons (this makes dissipative effects very small!). # contacts couple to the difference ΔA of the classical gauge potentials and of the order parameters describing topologically condensed coherent photons associated with the two space-time sheets joined by the # contacts. This provides the needed coupling to the classical fields and to the coherent photons generated by micro-tubuli serving as quantum antennas. # contact BE condensate couples also to the geometry of the boundary of the 3-surface since the action defining the dynamics contains the induced metric of the boundary regarded as a dynamical variable. In the present context this coupling is not important.

The complex order parameter for # contacts satisfies d'Alembert type wave equation with minimal coupling to ΔA. The order of magnitude for the lowest excitation energies is $\Delta E \sim 1/L$, where L is the size of the join along boundaries/flux tube condensate to which the # contacts are associated. The mass of # contact is from p-adic length scale hypothesis inversely proportional to the p-adic length scale $L(p)$ associated with the larger space-time sheet: $m \sim 1/L(p)$. For instance, for cell membrane the relevant p-adic length scale is roughly the thickness $L(p) \sim d \sim 10^{-8}$ meters of the cell membrane and one has $m(\#) \sim 10^2$ eV. Because of their small mass # contacts form a BE condensate, when temperature is below $T \sim 1/L$ (this estimate is probably too conservative): in the room temperature the largest size of join along boundaries/flux tube condensate would be thus of order 10^{-4} meters, which is indeed the size of largest known information processing structures in cortex [K23]. It must be emphasized that thermal argument is probably conservative: large space-time sheets need not be in thermal equilibrium with atomic space-time sheet and in fact they are *not* in the TGD based realization of living matter as a hierarchy of weakly coupled superconductors. By their extremely small coupling to photons # contacts (photonic dissipation is minimal) might be able to form BE condensates even above $T \sim 1/L$. As far as mathematical description is considered, charged # contacts behave very much like Cooper pairs. In particular, the concept of Josephson junction generalizes.

For # contacts "Josephson junctions" are join along boundaries bonds/flux tubes connecting the lipid layers together on the smaller space-time sheet, the larger space-time sheet is a connected surface. These bonds could correspond to weak chemical bonds between the hydrophobic ends of the lipids and need not be stable. Also the proteins connecting lipid layers could serve as Josephson junctions. Josephson junctions are idealized with a continuous distribution so that one can imagine a continuous sheet of thickness $d \sim 10^{-9} - 10^{-10}$ meters between the lipid layers serving as a single Josephson junction. Join along boundaries contacts make possible the motion of the # contacts between the join along boundaries/flux tube condensates associated with the lipid layers. This induces a coupling between the order parameters associated with the two lipid layers. One obtains Sine-Gordon equation coupled to gauge potential by generalizing the argument of Josephson from Schrödinger equation to almost massless d'Alembert type wave equation for the order parameter describing the BE condensates of # contacts at the boundaries of the two join along boundaries/flux tube condensates. Sine-Gordon coupled to a gauge potential difference is obtained directly whereas for the Cooper pairs Sine-Gordon is obtained from the Maxwell equation $\nabla \times B = J$ by assuming that order parameter satisfies covariant constancy conditions, which in turn forces to make ad hoc assumptions and would lead in the recent case to difficulties.

Field equation for the phase difference

The basic assumptions of # contact models are following. For definiteness only axon (of radius R, typically of order $R \sim 10^{-6}$ meters) is considered. Lipid layers are regarded as cylindrical surface of thickness d of order $d \sim .5 \times 10^{-8}$ meters. The distribution of the flux tubes serving as Josephson junctions is replaced with a continuous density of the flux tubes of thickness of order $10^{-9} - 10^{-10}$ meters. The order parameter is assumed to have approximately constant modulus

$$\bar{\Psi}\Psi \approx constant \ . \tag{8.4.29}$$

This requires that # contact flow between the lipid layers induces only small fractional changes in the total charge. The phase of the order parameter is assumed to depend on the time coordinate t and the longitudinal coordinate z of axon only.

The order parameter is assumed to satisfy linear d'Alembert type equation derivable from an action containing no higher nonlinearities than quadratic mass terms. General Ginzburg-Landau type action for the order parameter allows also quartic nonlinearities. These couplings are indeed needed to guarantee the stability of the system but are not relevant for the recent discussion. The action contains also a coupling to the geometry of the boundary regarded as dynamical. The coupling is via the induced metric and the corresponding field equations are analogous to the conservation laws for energy momentum. Also this aspect is irrelevant for the recent purposes although it might be important for the understanding of the geometrodynamics of the cell membrane during the nerve pulse propagation (the opening/closing of various ion gates corresponds to a change of the topology for the cell membrane 3-surface).

Consider now the derivation of Sine-Gordon type equation for the phase difference associated with # contact condensates. The difference with respect to the standard derivation is that # contacts satisfy $-$ not Schrödinger equation $-$ but d'Alembert equation with very small mass and couple to the difference of gauge potentials associated with larger and smaller space-time sheet. Of course, nothing hinders using relativistic formulation also in case of ordinary super-conductors.

The coupling between the order parameters associated with the boundaries of two lipid layers is represented by a non-diagonal mass squared term $J_1 = \frac{1}{\Lambda^2}\Psi_2$, $J_2 = \frac{1}{\Lambda^2}\Psi_1$. Taking $x^0 = vt$ as time coordinate the equations read

$$\begin{aligned}
(D + m^2)\Psi_1 &= J_1 = -\frac{1}{2\Lambda^2}\Psi_2 \ , \\
(D + m^2)\Psi_2 &= J_2 = -\frac{1}{2\Lambda^2}\Psi_1 \ , \\
D &= D_\mu D^\mu = D_0^2 - \sum_i D_i D_i \\
D_\mu &= \partial_\mu + iQ\Delta A_\mu \ .
\end{aligned} \tag{8.4.30}$$

Q denotes the charge of # contact: if # contact is created, when electron is dropped from the atomic space-time sheet on the larger space-time sheet then its charge is positive: $Q = e$. Note that field equation of the same general form can be derived for weakly coupled superconductors quite generally.

If the fractional changes of the charge densities caused by Josephson current are small, the assumption that the moduli of Ψ_i are equal to same constant is a good approximation. Thus the ansatz is of the following general form

$$\begin{aligned}
\Psi_i &= R_i exp(i\omega t + \Phi_i) \ , \quad i = 1, 2 \ ; \\
\omega &= mv
\end{aligned} \tag{8.4.31}$$

where $R_i = R$ is constant in the approximation used and v is the possibly reduced light velocity. By taking the difference for the imaginary parts of the field equations one obtains the following equation

$$D^{\mu}(\partial_{\mu}\Phi + Q\Delta A_{\mu}) = -\frac{1}{\Lambda^2} sin(\Phi) \ . \tag{8.4.32}$$

for the difference $\Phi = \Phi_2 - \Phi_1$ of the phases of the order parameters Ψ_1 and Ψ_2. This equation is 1+2-dimensional Sine-Gordon equation coupled to the gauge potential difference and reduces to Sine-Gordon if ΔA is small compared with the gradient of Φ. This is assumed to hold true in the sequel. It must be however emphasized that this coupling provides an important back-coupling term in the interaction between ordinary matter/coherent photons and the BE condensate of # contacts.

In cylindrical geometry the solutions can be assumed to be independent of the angle coordinate and one has 1+1-dimensional Sine-Gordon equation

$$\begin{aligned} (-\partial_0^2 + \partial_z^2)\Phi &= \frac{1}{\Lambda^2} sin(\Phi) \ , \\ x^0 &= vt \ , \end{aligned} \tag{8.4.33}$$

known to be a completely integrable system [B5] .

8.5 TGD And Biochemistry

TGD brings in several new elements at the level of biochemistry.

1. Macro-temporal quantum coherence due to the spin glass degeneracy.

2. The geometric form of the bio-molecules ceases to be a phenomenological concept in TGD approach.

3. Chemical bond can be identified as the join along boundaries bond/flux tube between two 3-surfaces.

4. # contacts might be the crucial step from the ordinary organic chemistry to biochemistry. For # contact superconductivity the conditions are rather mild since in TGD context the presence of light # contacts and thus their BE condensates is almost unavoidable. The hypothesis that some organic molecules might behave as # contact super conductors suggests a completely new manner to understand the bio-control at the level of DNA and proteins.

5. Almost vacuum space-time sheets carrying non-vanishing vacuum currents are possible in TGD and these currents generate coherent states of photons. The topologically condensed coherent photons can couple to the # contact BE condensates. Comorosan effect [I92, I33] is a good example of a phenomenon having an explanation in terms of a molecular # contact BE condensate coupling to coherent photons [K121].

6. Nuclei can be regarded as completely ionized Z^0 ions and generate classical Z^0 fields screened by neutrinos. Z^0 fields seem to be fundamental for the understanding of the condensed matter stability and also the stability of molecules. The quantum control of the density of cellular water could explain the extreme effectiveness and sensitivity of catalysts. The axial part of classical Z^0 field can in turn explain the chirality selection of organic molecules in vivo. The central role of Z^0 force in biochemistry and pre-biotic evolution has become obvious only gradually and will be discussed in a separate section.

8.5.1 Macro-Temporal Quantum Coherence And Molecular Sex

The formation of bound states is a generic mechanism for generating new quantum fluctuating degrees of freedom and could make possible quantum computation like processes and multiverse states of consciousness containing large amounts of conscious information. At macrolevel sexual organism could be basic example of multiverse state of oneness generated by the formation of quantum bound state between partners. Neuroscientists use to talk about rewards and punishments and one might argue that life involves kind of sexual pleasure as a reward for the formation of bound states at all levels of hierarchy. Spiritual experiences would represent a more abstract experiences of this kind involving the formation of bound states of the field bodies by MEs serving as field bridges.

Some examples are in order.

1. The binding of molecules by lock and key mechanism is a fundamental process in living matter and could generate large number of quantum fluctuating degrees of freedom and generate conscious intelligence. This could explain why long linear macromolecules are so important for life. From the viewpoint of classical chemistry it is not obvious why DNA is arranged into long chromosomes rather than separate short threads. In TGD universe the reason why would be that for chromosomes the number of quantum fluctuating degrees of freedom and thus the amount of conscious intelligence is maximized.

2. The Ca^{++} ions binding to micro-tubuli and molecules like calmodulin could act as switch like bridges between water clusters and micro-tubuli and thus able to dramatically increase the number of quantum fluctuating degrees of freedom and initiate quantum computation like process. The de-attachment of Ca^{++} ions would halt the process.

3. The binding of the information molecules to receptors is a universal control mechanism in living matter. In TGD universe information molecule would initiate genuine quantum information processing lasting for the lifetime of the information molecule-receptor complex. In particular, neurotransmitters could induce molecular states of oneness in receptor-neurotransmitter complex or perhaps even in larger-sized structures. If neurotransmitters have flux tubes to other neurons mediated by magnetic flux tube structures, they could act as conscious quantum links in quantum web and induce quantum computation like processes involving distant neurons just as link links in the web induce classical computations involving distance computers.

4. One could see information molecules and receptors as representatives of opposite sexes: information molecules being active quantum binders free to move from flower to flower whereas receptors would be the passive party attached to some structure. The binding of the information molecule to the receptor would be the analog of sexual intercourse. Usually the receptors are bound to larger structures such as cell membrane and also the zero modes for some parts of these larger structures could become quantum fluctuating in the process.

8.5.2 Organic Polymers As Topological Field Quanta

Organic polymers, in particular proteins formed as sequences of 20 different amino acids and DNA and related molecules formed as sequences of 4 basic nucleic acids, are the basic molecules of living matter and their characteristic features are their effective one-dimensionality and richness of structures. For example, proteins and nucleic acids can have several conformations: they can behave like aperiodic crystals or as random coils. Muscle proteins in turn can change their length in the contraction of the muscle. The conformation of the polymers is known to be sensitive to its electronic structure and to the properties (in particular pH) of the ionic environment. The chemical properties of silicon are very similar to those of carbon but for some reason(s) only carbon based life has developed.

A good TGD based model for organic polymers is as topological field quantum with approximate cylindrical symmetry. Linear structures are indeed in a very special position in TGD since the embedding of the Kähler electric field associated with the field quantum gives no constraints on the length of the field quantum.

8.5.3 Organic Molecules As Super-Conductors

The basic organic molecules appearing in regulative tasks (co-enzymes, vitamines, hormones) contain closed rings for which electron pairs are known to be de-localized along the ring, so that they could form superconductor. Also the basic building blocks of DNA contain closed rings although conjugated π bonds are absent [I81] . It is quite possible that the vacuum quantum number n_i

associated with these loops are non-vanishing and therefore carriers of a biological information. Electronic superconductivity is not the only possibility: also # contacts could form supra currents flowing in these loops.

The changes in the vacuum quantum numbers associated with the closed loops of the organic polymer are generated by a phase slippage [D59]. Phase slippage generates a localized kink, which corresponds to a supra current analogous to a nerve pulse. An interesting possibility is that these kinks might control biochemical reactions.

Possible applications

One can imagine several applications for these excitations in the bio-control.

1. For the biochemical reaction to proceed it is necessary to have free energy, which enables to overcome activation energy barriers. This energy should be stored to the structure of the catalysts and possibly also of substrate in some form [I81]. According to [I81] the storage mechanism is not established yet. What certainly happens is that free energy liberated, when catalyst and substrate join together, must go to some degrees of freedom. One suggestion is that the vibrations of the compound molecule serve as a storage of free energy [I81]. The first TGD inspired alternative is that the free energy liberated in the joining of catalyst and substrate is stored to the kinetic energy of the supra charge carries rotating along the loops of the compound molecule (quantum number n_i) and can be used as an activation energy storage helping to overcome the activation energy barriers. As already noticed, the energy liberated form ATP is of the same order as the kinetic energy associated with a rotating charge carrier. A more radical TGD based alternative is that the loops of the organic molecules in vivo contain additional negentropy in the form of the slowly dissipating supra currents.

2. Josephson junctions between two super-conducting organic molecules (say the two strands of DNA) are possible [D59] are possible. Hydrogen bonds are good candidates for these Josephson junctions. An oscillating Josephson current flows in the junction [D59]. In presence of several junctions destructive interference can take place between the currents provided there are phase differences between various junctions if there are supra currents flowing in the rings of the two molecules joined together by several hydrogen bonds (say DNA double helix). The composite structure (say DNA double helix) is expected to become unstable if too large total Josephson current runs through the junctions. Therefore the supra currents can act as a stabilizing mechanism for the composite molecule and the decay of the molecule takes place, when supra current dissipates by phase slippages.

Why # contacts/Cooper pairs are ideal tools of bio-control

There are several good reasons for why # contacts/Cooper pairs could provide a tool of bio-control.

1. # contacts/Cooper pairs are in the same quantum state and therefore they serve as a source of negentropy and one can consider the possibility that the BE condensate of the charge carriers is actually the carrier of the most relevant bio-information. In case of the enzymes this negentropy would provide a source of free energy needed to overcome activation energy barriers in the catalysis of the various chemical reactions. The dissipation associated with the motion of the charge carriers resulting from the phase slippage mechanism is very small. Phase slippage in n_i takes typically by the splitting and rejoining of a join along boundaries bond/flux tube. A measure for the rate of dissipation is the frequency for the splitting of the bond. The larger the bonding energy of the chemical bond, the smaller the rate of splitting is expected to be.

2. The complex order parameter describing the quantum state can be assumed to be covariantly constant in the ground state since the induced gauge fields are expected to vanish on the boundaries of the 3-surface. For Cooper pairs in the interior of 3-surface this assumption is probably also a reasonable approximation. As can be found in [K51], some information about the homotopy of the 3-surface is directly coded into the phase of the ground state order parameter for supra phases and same holds true for # contacts, which couple to the difference of the gauge potentials associated with the two space-time sheets. Since the creation and

destruction of the flux tubes changes the homotopy of 3-surface and since flux tubes are crucial for the properties of the macroscopic quantum system, this phase information is expected to be also biologically relevant. The spatial constancy of the density of # contacts /Cooper pair implies that the effects caused by the # contact/Cooper pair density are global so that the changes in the density produce co-operative effects.

3. In TGD the "act of free will", which is the most characteristic feature of bio-system, corresponds to a quantum jump between quantum histories. The quantum jumps induced change in the properties of the effective space-time and the BE condensate associated with it and the relevant aspects of the change could therefore correspond to the change of the order parameters describing # contacts/Cooper pairs and coherent states of photons.

4. The conformations of the organic molecule are expected to be sensitive to the distribution of the # contacts/Cooper pairs. The creation of an in-stability leading to a new conformation would correspond to the generation of a region of a molecular 3-surface, which is a mall deformations of a vacuum extremal of the Kähler action. For instance, this kind of redistribution might lead easily to the destruction or creation of the flux tubes. The same of course applies to the Cooper pairs and it is known that the conformations are sensitive to the electronic configuration. It could however be that the electronic configurations are not the fundamental controllers but are controlled by the configurations of # contacts behaving as classical charges.

5. By their lightness (having inertial mass of order $1/L(n)$ on dimensional grounds), # contacts provide a rapid mechanism for control and the classical field energy needed to accelerate # contacts is small (recall that # contacts couple to the *difference* of the gauge potentials associated with the two space-time sheets. The dissipation effects (not desirable in control and coordination signals) are extremely small since the coupling to ordinary photons (as opposed to topologically condensed coherent light) is extremely small dipole coupling (dipole with size of CP_2 radius is in question!). Also Cooper pairs are light and therefore very mobile and the kinetic energy associated with their motion (supra currents along closed loops and kinks) is very small and quantized, so that the density of the Cooper pairs could serve as an ideal control switch. For example, the kink of width L possesses momentum of order $p \simeq 2\pi/L$ ($\bar{p} = \nabla\Phi$ for Cooper pairs), so that its energy is $E = \pi^2/m_e L^2$, which is in general smaller than the de-localization energy.

6. The importance of the aqueous environment (with $pH \simeq 7$) for organic molecules might be related to the partial ionization of water in the following manner. There are two kinds of effects. The appearance of protons (about 1 per $10^{-25}m^3$) is expected to in-stabilize the polymer since it creates classical gauge fields interacting with # contacts/Cooper pairs leading to the generation of density gradients. On the other hand, the presence of the hydrogen bonded polymers of the water molecules has a stabilizing effect since the flux tube between an organic molecule and structure of this kind increases the de-localization volume for the charge carriers.

contacts or Cooper pairs of both?

contact superconductivity at all levels of the # condensate, in particular in the case of organic molecules, seems almost unavoidable. A possible explanation for why it is not observed is the extremely weak interaction of the # contacts with ordinary photons and the interaction with laser light provides a test for the idea. The Comorosan effect involving the interaction of the laser light with organic molecules could in fact be regarded as a positive evidence for the concept.

In case of electrons, superconductivity is not at all obvious and the standard wisdom about macroscopic superconductors excludes this possibility. In TGD context, the dropping of electrons on larger space-time sheets could make it possible to have also electronic superconductivity. The interaction between electrons induced from the interaction of the electrons with the # contacts creating the excitations of # contact BE condensate, could give rise to the formation of the Cooper pairs.

In many-sheeted space-time particles topologically condense at all space-time sheets having projection to given region of space-time so that this option makes sense only near the boundaries of space-time sheet of a given system. Also p-adic phase transition increasing the size of the space-time sheet could take place and the liberated energy would correspond to the reduction of zero point kinetic energy. Particles could be transferred from a portion of magnetic flux tube portion to another one with different value of magnetic field and possibly also of Planck constant h_{eff} so that cyclotron energy would be liberated. In the following only the "dropping" option is discussed.

flux tube makes possible the de-localization of the valence electrons. The pairing of the valence electrons to the spin singlet states occurs invariably in this process. Valence electrons can de-localize to a volume of two neighboring atoms as in covalent bond or to a volume of several atoms as in case of the benzene ring. Hydrogen bond is related to the de-localization of the electrons in the saturated valence bonds, for example water molecules join together by a hydrogen bond. The hydrogen bond can be interpreted as a de-localization of the valence electron pairs to a volume of several molecules. In case of the ionic bond, the exchange of electrons between atoms takes place, so that atoms are ionized and an increase of the Coulombic binding energy is achieved.

If the de-localization of the electrons is complete, organic molecule becomes conductor. Even more, if the electrons are paired to spin singlet states a transition to superconducting phase might take place: in this manner it might be possible to minimize the increase of the electron kinetic energy implied by the Pauli Exclusion Principle. A possible mechanism of de-localization is the dropping of some electrons on larger space-time sheets from the atomic space-time sheets. In these sheets the density of charge is small and the interaction with # contacts could give rise to the formation of the Cooper pairs. An additional condition must be however met: the gap energy of electronic superconductor is extremely small unless the super conductor is effectively one-dimensional. The presence of weak magnetic fields guarantees this. Since the temperature at non-atomic space-time sheets can be extremely low, very weak magnetic fields are enough to achieve this.

The necessary condition for the appearance of superconductivity is that the de-localization energy of the electron given by the expression $E_{deloc} \simeq \frac{1}{2m_e\xi^2}$ is larger than the thermal energy and implies that critical temperature is of the order of $T_c \simeq 5\ eV = 0.5{\cdot}10^5\ K$, so that superconductivity is in principle possible in the biosphere.

The obvious counter argument against electronic super conductivity, is that in thermodynamic equilibrium the quantum numbers n_i vanish with a very high probability: the exponent $exp(-E/T)$ is extremely small. The point is however that living matter is not in thermodynamical equilibrium but rather an open system, to which entanglement entropy (rather than negentropy!) is fed continually. The entanglement entropy might be stored at molecular level to the supra currents and due to the small dissipation rate of supra currents these states are so long lived that thermodynamic equilibrium has not enough time to set up. The supra currents in turn might be created at the moment of the formation of the bio-molecule and guarantee the stability of the molecule. Later a model of DNA based on the idea that the closed rings associated with the basic units of DNA in vivo carry non-vanishing quantum numbers n_i DNA and guarantee the stability of double DNA helix, will be considered. If # contacts are the carriers of the supra current then the interaction with the ordinary, in particular thermal, photons is effectively absent and the thermodynamical argument does not apply. # contacts however couple to the topologically condensed coherent photons and this coupling might be crucial for the functioning of the bio-system. The TGD based explanation of the Comorosan effect [K121] is based on the assumption that this coupling exists.

Candidates for super-conducting organic molecules

Promising candidates for superconducting organic molecules are the compounds containing cyclic structures since the de-localization of the electron pairs is known to occur for certain hydrocarbon rings through the formation of the so called conjugated π bonds [I81]: benzene is a classic example of this phenomenon. In this case electronic super currents would correspond to $n_1 \neq 0$ excitations of the electron pairs with kinetic energy of order $n_1^2\pi^2/4m_eL^2$, where L is the radius of the loop in question: energies are of the order of few electron volts. For # contacts the energy is of order $\pi/L(n)$, where $L(n)$ is the relevant (actually p-adic) length scale.

Very many important organic monomers possess carbon rings of this type and the rings are good candidates also for the carriers of # contact supra currents.

1. The compounds AMP, ATP and ADP, which serve the role of energy batteries contains rings of this type. Also coenzymes, vitamines and hormones having central role in biological control contain rings of this type. One might well imagine that superconductivity appears in the single ring, so that non-vanishing supra currents correspond to non-vanishing quantum numbers n_1 associated with these rings. The excitation energies ($E = n_1^2\pi^2/m_eL^2$ for a loop of size $L \simeq 10^{-9}$ meters are typically of the order of electron volt).

2. Amino-acids, which serve as the basic building blocks of the proteins, do not contain any closed rings but the biologically active α helix form of the protein contains hydrogen bonds between the NH and CO groups and these bonds might might make # contact/ordinary superconductivity possible. In biologically nonactive random coil form these bonds are absent [I81]. This suggests that the presence of the supra phase indeed is what makes dead matter living.

3. Nucleic acids, the building blocks if DNA and related molecules, contain nitrogenous bases, which are rings but do not contain conjugated π bonds, so that it is not clear whether supra current are possible in this case. There are however indications that DNA is a source of the visible light [I15]. A possible TGD based explanation for this effect is as light emitted in the de-localization of the Cooper pairs. Biologically active helix form of DNA is also optically active unlike the random coil form [I81].

4. For the electronic superconductivity, the gap energy for $L \sim 10^{-8}$ meters corresponds to the energy of the photon of the visible light, so that visible light is expected to be a particularly effective localizer of a Cooper pair. An interesting question is whether this sensitivity might provide additional insight to the understanding of photo-biochemical reactions, in particular photosynthesis, and the mechanism of the vision. In fact, the decay of an electron pair to unpaired electrons is known to take place, when chlorophyll molecule absorbs photon [I81], which suggests that photon energy goes directly to the de-localization of the Cooper pairs. The hypothesis explains also why vision is sensitive to visible light only. Also the excitation of the # contacts from ground states on the boundaries of a surface having size of order cell size would involve photon absorption.

8.5.4 Bio-Catalysis And TGD

The main function of the proteins (sequences of amino-acids) is to serve as catalysts for various biochemical reactions. The characteristic feature of the biochemical reactions is extreme selectivity, which necessitates an effective recognition mechanism between bio-molecules.

The simplest model for the catalytic action is the lock and key mechanism. The catalyst and substrate fit together like lock and key. This kind of a mechanism is indeed very natural in TGD inspired picture and corresponds to a partial join along boundaries bond/flux tube connection. The lock and key mechanism fails to describe all features of the bio-catalysis: the conformations of the bio-molecules are known to be dynamic rather than static and sensitive to the electronic configuration. A refined version of the lock and key mechanism is the so called induced fit [I81]. The structures of the substrate and catalyst are not assumed to be static anymore. When substrate and catalyst have joined together they can change their conformational structures before the reaction takes place. TGD indeed predicts that the conformation of the resulting state is in general unstable. After the join along boundaries reaction however, a redistribution of # contacts/Cooper pairs in the whole reaction volume takes place and the conformation changes until a minimum of E is found.

By the previous considerations # contact BE condensates associated with the organic molecules could play important role on the catalytic mechanism. What happens in the Comorosan effect is that the stimulation of the organic molecules with laser light lasting a multiple of basic period $\tau \sim 5$ seconds enhances the catalytic activity. The TGD based explanation of the Comorosan effect [K121] relies heavily on the assumption that the Josephson junctions formed between enzyme and substrate molecules affects the rate of the reaction and also explains all the mysterious looking regularities of with the effect [I92, I33].

8.5.5 TGD Inspired Model For The Unwinding And Replication Of DNA

As an example consider a TGD inspired model for the unwinding and replication of DNA molecule. The unwinding is known to proceed either spontaneously or with the help of DNA polymerase during replication [I81]. It has turned out to be difficult to understand the mechanism behind the spontaneous unwinding of the double helix [I81]. The replication takes place in the following steps. The presence of the DNA polymeraze attached along the double helix causes the unwinding of the double helix by setting the strands in a rotational motion in the same direction and by splitting the hydrogen bonds between the nitrogenous basis of the composite strands. The hydrogen bonds are formed between the cyclic nitrogenous bases A(denine), C(ytocin), G(uanine) and T(hymine) and only A-T and C-G bonds are possible.

The difficulties are related to the understanding how the unwinding can take place so rapidly [I81]. The simplest mechanism explaining the unwinding is based on the assumption that DNA molecule rotates very rapidly along its axis at the beginning of the unwinding process. If one fixes the second end of the double strand then unwinding takes place automatically and the angular frequency for the unwinding is essentially equal to the rotation frequency. The estimate for the angular frequency of the rotation is however very large even for the shortest DNA molecules (having length of about 10^{-8} meters): rotation frequency is about 10^4 times per minute! This doesn't look sensible since dissipation should destroy the rotation of DNA rapidly. In fact this rotation rate corresponds to an angular momentum of few Planck units and this suggests that quantum effects are involved.

First model

The simplest TGD based model for the unwinding is based on the following assumptions. The model is formulated assuming that # contacts are the carriers of the supra current but it applies also in case of the Cooper pairs.

1. There is a condensate of # contacts along the whole DNA molecule. # contact supra current flows in the loops of DNA strands in same direction, so that there is a net angular momentum associated DNA molecule. The integers n_i associated with all loops along DNA molecule are identical by the complete de-localization of the charge carriers. Since supra phase is in question the dissipation rate for this angular momentum is low unlike for the ordinary rotational angular momentum of the double strand.

2. There are two mechanisms leading to the unwinding of the DNA molecule.

   (a) The destruction of some # contacts takes place so that the angular momentum of these pairs is transformed to the rotational angular momentum of the DNA molecule itself. The disappearance of the # contacts involves the transfer of charge between space-time sheets and might well involve a transfer of electrons from the “larger” space-time sheet to the atomic space-time sheet. Hence also the disappearance of the Cooper pairs from the larger space-time sheet (if present there) might be involved.

   (b) Phase slippage takes place along the whole DNA molecule, so that the integers n_i characterizing the behavior of the order parameter change in all loops along DNA and the angular momentum is liberated to a coherent rotational motion of the whole DNA molecule. The phase slippage liberates angular momentum of order $J = N_c \Delta n_1$, where N_c is the number of the # contacts in the molecule. For the shortest DNA molecules N_c should be about one. In general, the linear density of the # contacts should be about one pair per 10^{-8} meters.

3. If the second end of DNA molecule is fixed, DNA molecule unwinds. Otherwise the angular momentum of the DNA molecule is gradually dissipated.

Second model

The splitting of the double strand into single strands might be caused by the mere unwinding. It is also possible that the Josephson currents of # contacts are involved in the process. A more refined TGD inspired scenario for the unwinding and replication of DNA looks like follows.

1. The cyclic rings associated with the complementary bases are carriers of # contact supra currents. The hydrogen bonds between the rings (2 or 3 depending on situation) can be regarded as Josephson junctions. Therefore an oscillatory Josephson current flows between the complementary basis in the double helix of DNA. If the supra currents in the basis loops rotate in the same direction, the phase differences between the hydrogen bonds are maximal and a destructive interference between Josephson currents occurs and guarantees the stability of the double helix. Since the currents rotate in the same direction there is a net angular momentum associated with these supra currents.

2. The dissipation caused by the phase slippages implies that this supra current becomes small in the course of time. This can take place in several steps or in single step depending on the value of n_1. This effect is collective and take place for all loops of the DNA molecule propagating in a wave like manner from one end of the molecule to the second end. If the second end of the DNA molecule is fixed, this process leads to the unwinding of the DNA molecule.

3. When the critical phase slippage occurs, Josephson current achieves the critical value making the double helix structure unstable, so that the hydrogen bonds break and this leads to the splitting of the double strand.

4. The role of the DNA polymerase in DNA replication is to keep the second end of DNA fixed and possibly to generate the supra current kink, which interferes destructively with the super current in loops and leads to the amplification of the Josephson current.

5. The replication of the resulting strands is achieved by introducing the complementary nucleotides. The formation of the double DNA strand can be regarded as a time reversal of the unwinding of the double DNA. In this case catalyst must take care that correct pairs are glued together by the hydrogen bonds. The formation of the stable hydrogen bonds is possible only provided non-vanishing supra currents are generated in the loops associated with the complementary nitrogenous bases. Angular momentum conservation implies that the strands get into a winding motion provided the direction of the supra currents is correct. DNA double helix is formed.

6. The process doesn't lead to the unwinding of DNA unless the second end of DNA is fixed. In case that no unwinding occurs, there must exist some mechanism regenerating the original supra current in the DNA molecule since otherwise DNA molecule would gradually lose its angular momentum and its ability to unwind and replicate. In fact, the presence of the supra current might be essential for the stability of DNA and the rejoining of the hydrogen bonds after the phase slippage might automatically generate the needed supra current. In this process a feed of negentropy from the environment to DNA molecule obviously takes place.

8.6 TGD And Morphogenesis

Morphogenesis, that this the formation of the spatial bio-structures during the development, is one of the not so well understood biological phenomena [A14]. There are several problems related to this phenomenon.

1. What dictates the size and the form of the bio-structures?

2. What are the basic control mechanisms altering the size of the existing structures, say, the length of the muscle?

3. What are the mechanisms controlling morphogenesis? What is the clock, or rather the alarm clock, taking care that the division of a cell or the formation of an organ during the morphogenesis begins at certain time? How is the information about the formation of the spatial structures contained in the developing embryo? How is the spatial ordering and synchronization of several parallel processes achieved?

In the sequel the generation of both spatial and temporal structures is considered and an actual realization for biological clocks and biological alarm clocks as supra current circuits by generalizing the ideas of the TGD based model of nerve pulse and EEG, is proposed. The role of genome in the control of the morphogenesis will be considered only very briefly and the ideas related to many-sheeted DNA are left to a separate chapter [K55].

8.6.1 Topological Field Quantization And Vacuum Quantum Numbers

Topological field quantization provides a TGD based first principle explanation for the existence of the spatial structures. The size of the bio-structure depends on the vacuum quantum numbers and is dictated by the stability criterion (the sum of Z^0 Coulomb energy and electronic de-localization energy is minimized). The hypothesis that bio-systems are superconductors at the first level of the condensation implies that supra currents are a basic tool of the bio-control. The density of the charge carriers dictates the stable size and form of the organ and also the nontrivial phase information carried by the order parameter is expected to be important.

There are handful of vacuum quantum numbers arising from the time and spatial behavior of the phase angles ϕ_i associated with the two complex CP_2 coordinates [K51]. One can express the dependence of these phase angles on space-time coordinates as a sum of Fourier expansion plus zero mode term linear in some coordinates and not allowing Fourier expansion. In linear Minkowski coordinates the vacuum quantum numbers would define components of four-momentum. In spherical coordinates vacuum quantum numbers correspond to frequency, momentum in given direction plus integer analogous to the component of the angular momentum in the direction of momentum. The set of vacuum quantum numbers associated with the two phase factors depends on the choice of the coordinates for M^4_+ and CP_2 and involves a selection of maximal number of mutually commuting observables in the Lie-algebras of Poincare group and color group. This is consistent with the fact that topological field quantization indeed is the classical counterpart of quantization. The construction of quantum TGD and understanding of the p-adic aspects of quantum TGD involves in an absolutely essential manner the choice of these quantization axes.

To fix the notation, the quantum numbers associated with the spherical coordinates will be denoted by (ω_i, k_i, n_i), $i = 1, 2$. detailed definitions of vacuum quantum numbers reader should consult the appendix of this book and [K51]. The first consequence is that given space-time sheet is characterized by two frequencies. A good working hypothesis is that the frequency difference associated with two space-time sheets connected by Josephson junctions corresponds directly to the voltage difference over Josephson junction: $\Delta\omega_1 = ZeV$. Besides the group theoretical quantum numbers topological field quantum is characterized by a fractal quantum number m, which roughly tells which power of fixed scaling is applied to standard topological field quantum to obtain the topological field quantum in question. An interesting possibility is that m might be related with p-adic scaling $x \rightarrow p^m x$. For a detailed definition of vacuum quantum numbers the reader can consult the appendix of this book.

8.6.2 Vacuum Quantum Number Changing Phase Transitions And Morphogenesis

In ordinary physics space-time is a fixed arena for the dynamics of the quantum fields. The space-time serves as a master and fields serve as slaves. The enormous vacuum degeneracy of the Kähler action suggests that the situation might be just the opposite for bio-systems in the TGD Universe. If the space-time surface is a small deformation of a vacuum extremal, there is indeed a good reason to expect a large ground state degeneracy (spin glass analogy) in the sense that ground states correspond to different configurations for 3-surfaces. In the bio-systems, the order parameter associated with some macroscopic quantum system could induce changes between these ground states and thus give rise to the changes of the macroscopic geometry and even the topology of the space-time sheet.

Suppose that the order parameter, serving as a master, changes so that the covariant constancy condition for the order parameter characterizing the ground state of the supra phase is not satisfied anymore. As a consequence, space-time topology changes, new join along boundaries bonds/flux tubes are created and old are destroyed. The end result is that covariant constancy condition is satisfied in the final state. The size, shape and even the topology of the organ could change in this kind of phase transition. Self-organization is expected to lead to an asymptotic states in which covariant constancy conditions hold true. These covariant constancy conditions in time direction and in the direction of Josephson junction are indeed absolutely essential in the general model of Josephson junction leading to Sine-Gordon equation.

8.6.3 Vacuum Quantum Numbers And The Size Of The Organ

The appendix of this book provides detailed information about vacuum quantum numbers (form more details see [K51]). Besides two Poincare quantum numbers (ω_i, n_i, k_i) $i = 1, 2$, there is also fractal quantum number m characterizing the members in a family of topological field quanta obtained from basic topological field quantum by iterating discrete scaling whose magnitude depends on topological field quantum. The considerations "Macroscopic quantum phases..." suggest that various bio-molecules and the structures formed by them correspond to the value of $\omega_1 = (10^{2.5} - 10^3)m_p$ and that cell and cell membrane could be identified as corresponding to structures having the values of fractal quantum number $m = 0$ and $m = 2$ respectively and $\omega_1 = (10^5 - 10^6)m_p$. There are good reasons to expect that larger organs correspond to larger values of ω_1 and that surface structures in general correspond to larger values of the fractal number.

There are reasons to expect that the value of ω_1 at the atomic condensation level is very rigid. At the other condensation levels the situation is not so clear but the property of being a preferred extremal of Kähler action implies generalized Bohr rules, and together with quantum self-organization suggests that the values occurring in nature vary in very strict bounds. The fact that cell sizes vary between certain limits (typically $10^{-6} - 10^{-5}$ meters) might result from the variation of ω_1 by a factor of ten. If this is the case the growth of an organ or organelle, say cell, would correspond to a gradual increase of the parameter ω_1 at the appropriate level of condensation. It would be tempting to postulate that the variations in the value of ω_1 become larger the higher the level of condensation is.

Homology is a very general biological phenomenon. Same basic structure (for instance five fingers, spinal cord, etc..) appears with various sizes and detailed forms in different species. The simplest explanation is that these structures develop from identical initial structures but that the values of the vacuum quantum numbers, in particular ω_1 and possibly also the fractal quantum number m are different for these structures, so that the critical sizes are different. The differing sizes of the individuals belonging to the same species could be explained in a similar manner although the values of the other vacuum parameters affect the size, too. Fractal quantum number m might explain the fractal structures observed in the organic matter at the higher condensation levels [A6].

8.6.4 Phase Transitions Changing The Values Of The Vacuum Quantum Numbers

The surface density of the # contacts is constant in the stationary situation. The larger the electromagnetic charge of the space-time sheet, the larger the total number $N(\#)$ of the # contacts near its boundaries. The perturbation of the # contact surface density is expected to lead to the in-stability in the shape and possibly also the size of the 3-surface if 3-surface corresponds to a small deformation of a vacuum extremal. One can also consider the possibility that the 3-surface contains some critical regions near vacuum extremals. An attractive simplifying hypothesis is that the 3-surface suffers a rapid deformation in such a way that the surface density $n(\#)$ of the # contacts is constant in the final situation. For instance, the reduction of # contact density at some section of a linear structure would generate a pinch and could lead to the splitting of the structure. This kind of mechanism is expected to lead to the splitting of the join along boundaries contacts.

Bio-systems consist mostly of water and hydrodynamics flows are in a good approximation incompressible, so that only the shape of the 3-surface is controllable. This suggests that, at least for sufficiently large space-time sheets, the volume of a given sheet of the 3-space is proportional to the number $N(\#)$ of the # contacts:

$$V = kN(\#) = kn(\#)A \ ,$$

so that the surface density of the # contacts would behave as

$$n(\#) = \frac{V}{kA} \ .$$

The smaller the surface density of the # contacts, the larger the surface area per volume and the more fractal the appearance of the surface. This is in accordance with the idea that for small surface densities of # contacts (and small total electromagnetic charges) 3-surface is nearer to a vacuum extremal and therefore the shape of the 3-surface becomes unstable.

These considerations suggests that the generation of the gradients in the density of # contacts or some other superconducting particles through the generation of the supra currents provide a control mechanism for the shape of the organ. Since # contacts couple to the difference ΔA of the classical gauge potentials associated with the two space-time sheets connected by # contacts, the changes in ΔA induce a change in the shape of the 3-surface. There is also a coupling to the difference of the order parameters (effectively classical gauge potentials) describing the topologically condensed coherent photons on the two space-time sheets in question. This could make possible for a coherent state of photons, perhaps generated by micro-tubuli and/or some other linear structures, to control the shape of the 3-surface.

The phase information is expected to be important even in the long length scales. A classic example, giving striking evidence for the presence of the complex order parameter in even macroscopic length scales, is related to the growth of a new "leg" or, actually its homological equivalent in lower organisms. The detailed description can be found in the book of Winfree [A3]. Suppose one removes left leg and replaces it with the right one. What happens is that two additional left legs grow! The explanation is based on the conservation of the phase difference around a circle surrounding the leg in the sense that this phase difference is constant along the leg. This quantum number is opposite for left and right legs: $n(L) = -n(R)$. In the situation considered the total quantum number is $2n(L) + n(R) = n(L)$.

At longer length scales, the changes of the vacuum quantum numbers affect the size and form of the organ.

1. The growth of the organ might correspond to a gradual increase of ω_1 and therefore of the stable size of corresponding field quantum.

2. A phase transition leading to a decrease of the quantum number ω_1 can take place for field quantum and reduces the size of a stable field quantum: this kind of phase transition implies the decomposition of the developing embryo into several sub-organs during morphogenesis.

To make these ideas more concrete consider some examples.

1. Cell division is the simplest example of a generation of a new structure and is difficult to understand in terms of purely biochemical concepts. The generation of the cellular membrane takes place spontaneously, when the mass of the growing cell becomes larger than some critical mass. The simplest model for the cell division is based on the decrease of the vacuum quantum number ω_1 at the cell level, so that the critical size of the cell decreases and cell divides. During the growth ω_1 increases until the critical cell size is achieved. At the first level of condensation the phase transition decreasing ω_1 must be triggered by some kind of an "alarm clock" to be discussed below.

2. Differentiation: the developing embryo divides at very early stage to a mosaic of separate regions, which later develop into various organs. Biochemical concepts do not throw much light to the description of this phenomenon and there are several indications [A14] that the phenomenon is topological rather than biochemical. For example, the number of the regions stays constant although the size of the embryo increases and is stable against external

perturbations and the number and general structure of the organs is same for all individuals of the species independently of their size. It is natural to identify these regions as topological field quanta, whose size is determined by the value of ω_1 and increases during the growth. The stability against external perturbations corresponds to the stability against topological changes.

8.6.5 Biological Alarm Clocks And Morphogenesis

In previous section very general model for biological alarm clocks based on weakly coupled superconductors was proposed. This kind of circuits could be an essential element of morphogenesis. Some examples are in order to show that this idea might have relevance.

1. The replication of cell is an extremely complicated process but could be understood as quantum self-organization process leading to final state pattern which only very mildly depends on the initial state. This process must be initiated by a "wake-up" of a self representing perhaps the cell. The alarm clocks must now be contained to the membrane surrounding the cell nucleus and probably also to the cell membrane since the cell membrane is known to be coupled to the division process of the cell nucleus, too [I81]. The reference currents are generated, when the new cell is born. The process leading to the replication of the cell could involve a reduction of the density of some super-conducting charge carriers in the critical region and this could initiate the decay of the cell. This is achieved if Josephson currents run away from certain region of the membrane of the cell nucleus implying depletion of charge carriers.

2. The generation of a completely new spatial structures during the morphogenesis is second extremely complicated process which should be understandable in terms of quantum self-organization. An example is afforded by the generation of somites [A14], which later give rise to brain and spinal cord. The homogenous longitudinal cell mass divides in a phase transition like manner into somites with clock wise regularity and the number of the somites is a constant characteristic for the species in question [A14]. The catastrophe theoretic models proposed in [A14] are based on the assumption that the pulse triggering the formation of somites is coupled to a biological clock, so that the motion of the boundary between differentiated and undifferentiated cell mass alternately slows down or fastens up and implies the generation of discrete regions, where the formation of the somites takes place.

   A qualitative TGD based description is provided by the alarm clock model:

1. There is certain biorhythm realized using Josephson junctions (rhythms (minute scale) of this kind have indeed been identified [A14]) at cell level.

2. Josephson currents flow between the cells belonging to the longitudinal cell mass and neighboring cells in transversal direction. Due to the presence of the cell level reference currents, Josephson currents interfere destructively and variations in density of charge carriers are small.

3. There is slow dependence of the phase of the order parameter ψ along the linear cell mass implying a phase lag between the clocks.

4. Reference current dissipates gradually through phase slippages and when the time is ripe the amplitude of the Josephson current becomes large and makes the density of charge carriers small inside the longitudinal region. The formation of the somites begins since the stability criterion implies that the stable size of topological field quantum decreases.

5. Time regulation is achieved through the presence of the biological clock: nothing happens unless the phase of the clock is correct since Josephson current runs to a "wrong" direction.

6. The process begins from the cells, which were born first since the clocks associated with them were created first and propagates in the order, in which the cells were born. In fact, the spatial dependence of the phase of the order parameter might code this order. The spatial dependence of the phase means that the rate for the propagation of the somite formation

varies with position and guarantees in this manner the formation of spatially separated structures (compare with clock wave front model of [A14]). The number of the somites is just the multiple of 2π: s that the phase of the order parameter increases along the longitudinal cell mass.

8.6.6 Could Vacuum Quantum Numbers Control Gene Expression Via Josephson Currents

Controlled and synchronized gene expression is the most fundamental aspect of morphogenesis and implies surprising determinism of the development. When developing organism achieves certain level of development, certain gene activates. This requires feedback mechanism from long length scales of size of order organ to the gene level. In standard physics, the most plausible mechanisms are chemical. Certainly it is very difficult to understand how organs size could control the activation of genes via chemical concentrations. Whether this is the case is an unanswered question as yet. In any case, the notion of many-sheeted space-time (see **Fig.** `http://tgdtheory.fi/appfigures/manysheeted.jpg` or **Fig.** 9 in the appendix of this book) provides a fresh view to this process.

TGD leads to the notion of many-sheeted DNA [K55], which means that DNA has # contacts to several space-time sheets. One can even consider the possibility that various space-time sheets associated with gene correspond to the expression domains of gene so that in a very abstract sense genome would be full grown organism compressed to a thin many-sheeted thread of thickness of order 10^{-8} meters and morphogenesis could be regarded as a decompression of this packed information. If self-organization determines what happens in transversal degrees of freedom, then one could say that gene codes the one-dimensional skeleton of the expression domain of the gene. Especially interesting from the point of view of bio-control are join along boundaries contacts connecting DNA space-time sheets with larger space-time sheets.

Many-sheeted space-time concept suggests hierarchies of biological alarm clocks whose ringing induces ringing of some clocks at a lower level of hierarchy so that finally the alarm clock waking-up and activating definite gene rings. A possible mechanism causing the ringing would be situation in which the potential difference associated with the Josephson junction becomes equal to the energy difference of a single particle state associated with either super-conductor: cyclotron resonance, which seems to be crucial for brain functioning and EEG, is basic example of this. This could at DNA level lead to the activation of gene and start up of a self-organization process. One could imagine complicated circuits in which ringing would occur only provided all required conditions are achieved. It must be emphasized that this option is not the only possible one and in [K37] a more plausible mechanism involving the new physics implied by TGD is developed.

The correlation of gene expression with the size of growing organ could be achieved as follows. If the potential difference corresponds to the difference of vacuum frequencies ω_1 associated with the coupled super conductors and if ω_i correlate with the sizes of the corresponding structures, the ringing of the clock would occur when the size difference is critical. If the first superconductor corresponds to some structure with a fixed size (say gene) and second superconductor corresponds to the growing organ, this mechanism would initiate new kind of gene expression when the growing organ reaches critical size.

Chapter 9

Quantum Control and Coordination in Bio-Systems: Part II

9.1 Introduction

This chapter is devoted to the aspects of quantum control and coordination involving the intentional action of the magnetic body and classical em and Z^0 fields. The previous chapters are warmly recommended in order to get an overall view about basic philosophy and ideas. The general understanding of the dynamics of Kähler action provides a considerable light to how topologically quantized induced Kähler field defines templates for bio-structures and for their self-organized dynamics. Time mirror mechanism is the most convincing mechanism for realizing intentional action discovered hitherto. The scalar wave pulses of Tesla might have TGD counterpart and provide perhaps the most elegant way to transform intentions to actions. Also the possible role of classical Z^0 force in condensed matter and bio-chemistry is discussed.

9.1.1 Preferred Extremals Of Kähler Action, Thermodynamics, And Biology

The vanishing of Lorentz 4-force for the induced Kähler field means that the vacuum 4-currents are in a mechanical equilibrium. Lorentz 4-force vanishes for all known solutions of field equations which inspires the hypothesis that at least the preferred extremals of Kähler action satisfy the condition. The vanishing of the Lorentz 4-force in turn implies local conservation of the ordinary energy momentum tensor. The corresponding condition is implied by Einstein's equations in General Relativity. The hypothesis would mean that the solutions of field equations are what might be called generalized Beltrami fields. The condition implies that vacuum currents can be non-vanishing only provided the dimension D_{CP_2} of the CP_2 projection of the space-time surface is less than four so that in the regions with $D_{CP_2} = 4$, Maxwell's vacuum equations are satisfied.

The hypothesis that Kähler current is proportional to a product of an arbitrary function ψ of CP_2 coordinates and of the instanton current generalizes Beltrami condition and reduces to it when electric field vanishes. Kähler current has vanishing divergence for $D_{CP_2} < 4$, and Lorentz 4-force indeed vanishes. The remaining task would be the explicit construction of the imbeddings of these fields and the demonstration that field equations can be satisfied.

By quantum classical correspondence the non-deterministic space-time dynamics should mimic the dissipative dynamics of the quantum jump sequence. Beltrami fields appear in physical applications as asymptotic self organization patterns for which Lorentz force and dissipation vanish. This suggests that the preferred extremals of Kähler action correspond to space-time sheets which asymptotically satisfy generalized Beltrami conditions so that one can indeed assign to the final (rather than initial!) 3-surface a unique 4-surface apart from effects related to non-determinism. Preferred extremal property stating that the extremal allows infinite number of deformations with a vanishing second variation of Kähler action abstracted to purely algebraic generalized Beltrami conditions would make sense also in the p-adic context.

This picture can be claimed to be internally contradictory since all known extremals would correspond to asymptotic self organization patterns. One should have space-time correlates also for the non-asymptotic situations.

1. The progress made in understanding the definition of the theory using the reduction to Kähler-Dirac action clarified the situation. It turned out that one must add to the Kähler-Dirac action a measurement interaction term coupling space-time geometry to conserved quantum numbers. One of the motivations for this was quantum classical correspondence. This induces also to Kähler action measurement interaction term and the asymptotic self-organization patters represented by the known extremals have the property that measurement interaction term vanishes.

   A further crucial step was the realization that well-definedness of em charge for the modes of induced spinor field forces their localization to 2-D surfaces in the generic case. These surfaces carry vanishing induced gauge fields and possibly also Z^0 field and naturally so above weak scale. This resolves problems related to the possible large parity breaking effects and makes strings part of TGD. One might understand large parity breaking effects in living way since for large values of $h_{eff} = n \times h$ weak scale is scaled up.

2. Also the long-standing issue relating to the identification of preferred extremals playing the role of Bohr orbits in positive energy ontology (in zero energy ontology Bohr orbit like behavior would mean strong correlations between the 3-surfaces at the opposite boundaries of causal diamond (CD)) and implying quantum holography was resolved. The preferred extremals defining the analogs of Bohr orbits must be critical in the sense of having an infinite number of deformations for which the second variation of Kähler action vanishes. The criticality of Kähler action would thus the basic dynamical principle of space-time dynamics and provide space-time correlate for quantum criticality required by quantum classical correspondence. Purely number theoretic conditions in turn lead to the conclusion that space-time surfaces must be hyper-quaternionic in the sense that the Kähler-Dirac gamma matrices span associative or co-associative plane at each point of the space-time surface. "Co-" means that the orthogonal complement of this plane is hyper-quaternionic (associative). Whether criticality and associativity (co-associativity) are consistent is not quite clear.

The intricate topological structures of DNA, RNA, and protein molecules are known to have a deep significance besides their chemical structure, and they could even define something analogous to the genetic code. Usually the topology and geometry of bio-molecules is believed to reduce to chemistry. TGD suggests that topologically quantized generalized Beltrami fields with space-like Kähler current serve as templates for the formation of bio-molecules and bio-structures in general. Indeed, Beltrami fields can be extremely complex but at the same time they are highly organized and ordered structures. The dynamics of bio-systems could in turn utilize periodic generalized Beltrami fields with time-like Kähler current as templates. There could even exist a mapping from the topology of magnetic flux tube structures serving as templates for bio-molecules to the templates of self-organized dynamics.

Thus the natural conjecture is that topologically quantized many-sheeted magnetic and Z^0 magnetic generalized Beltrami fields serve as templates for the helical molecules populating living matter, and explain both chirality selection, the complex linking and knotting of DNA and protein molecules, and even the extremely complex and self-organized dynamics of biological systems at the molecular level.

9.1.2 Time Mirror Mechanism As A Fundamental Mechanism Transforming Intentions To Actions

What causality means in TGD framework?

In order to minimize confusion it is in order to clarify the various meanings that one can give to causality in TGD framework.

1. At the level of space-time surfaces the criticality of the preferred extremals defines dynamics of the space-time surfaces and defines the causality of passive events at classical level. Induced spinors (spinors of the 8-D embedding space restricted to the space-time surface) obey the super-symmetric variant of field equations for the space-time surface and single particle Schrödinger equation can be identified as the non-relativistic limit for the dynamics of the induced spinor fields. The finite size of the space-time sheet defines naturally the notions of coherence length and time for both classical fields and spinor fields. In both cases classical determinism is broken in its naive form. For p-adic space-time sheets p-adic variants of field equations hold true and have the inherent p-adic non-determinism.

2. At configuration space ("world of classical worlds" (WCW)) level general coordinate invariance together with huge super-conformal invariance related symmetries can be said to dictate the behavior configuration space spinor fields playing a role analogous to quantum states of quantum field theories. If the naive classical determinism of Kähler were not broken, the physics would reduce to the boundary of the future light cone, the moment of big bang and time would be lost as in the canonical quantization of General Relativity. Fortunately this does not happen.

3. Quantum jumps can be said to realize the causality with respect to the subjective time, the causality of deeds. Selves can be seen as self-organization patterns acting as causal agents. At this level system's behavior is based on rules analogous to those governing the behavior of statistical cellular automatons and are a result of self-organization. The laws are not absolute but analogous to traffic rules obeyed or possibly disobeyed by intentional agents.

A further question concerns causal agents: everyday thinking suggests that deeds indeed have doers. In quantum consciousness theories based on standard quantum measurement theory doers are "observers" somewhere outside. In TGD causal agents are rather abstract: ensembles of quantum jumps deciding to some degree what kind of quantum jump they want to add to the ensemble defining them.

Materialization of intentions

Em fields, in particular ELF em fields, are crucial for the TGD inspired model of brain and a natural assumption is that p-adic–real phase transitions occur also for massless extremals (MEs).

A concrete picture about the materialization of intentions emerges, when one asks how a precisely targeted intention could be realized at the atomic or molecular level. The basic point is that molecules can only intend to make simple quantum transitions.

1. If the transition occurs to a lower energy state it can occur spontaneously whereas the transitions to a higher energy states cannot. Spontaneous transitions mask the possibly occurring intended transitions so that only the transitions which cannot occur spontaneously allow precisely targeted intention.

2. What would happen is that first a p-adic ME representing the intention to perform the transition is generated. Then the transition occurs and conservation laws require that the p-adic ME is transformed to a negative energy ME in the transition. Physical intuition suggests that the p-adic ME and the corresponding real ME resemble each other maximally in the sense that they go through the same rational imbedding space points in some p-adic resolution and with respect to the p-adic topology which is effective topology In the case of the real ME.

3. Quite generally, it seems that intention can be realized in a precisely targeted way only for the transitions which cannot occur spontaneously, and thus involve the emission of negative energy MEs.

4. The generation of negative energy MEs utilizes the buy now-let others pay mechanism of metabolism, which implies extreme flexibility. Of course, there must exist an unselfish self, which is able to pay and this puts severe constraints on the mechanism.

Time mirror mechanism, scalar wave pulses, and wormhole magnetic fields

Many-sheeted space-time makes possible many-sheeted lasers since cold space-time sheets can contain Bose-Einstein condensates of ions and their Cooper pairs. If the system contains population inverted many-sheeted laser for which the increment of zero point kinetic energy corresponds to the energy of photons associated with negative energy MEs, the absorption of negative energy photons gives rise to a phase transition like dropping of particles to larger space-time sheet by the induced emission mechanism, and the control signal represented by negative energy MEs can be amplified if a critical number of particles drops to the larger space-time sheet. This control mechanism allows an instantaneous motor control in which intention is transformed to desired represented by negative energy MEs and generates in geometric past a reaction representing the desired response, say neuronal activity giving rise to motor action. This process probably involves entire hierarchy of magnetic selves realizing their intentions as desires communicated to lower level magnetic selves and the lowest level corresponds to the regions of brain responsible for liberating metabolic energy.

The simplest possibility is that the transformation of the intention to action corresponds to p-adic-to-real phase transition for negative energy topological light ray. A generation of p-adic scalar wave pulse transformed to real one is an alternative mechanism assuming that scalar wave pulses are possible in TGD framework in some sense.

Are scalar pulses then possible in TGD? This might not be the case at the level of single space-time sheet. Many-sheeted space-time however allows to have parallel MEs with pulses travelling in opposite spatial directions. The test particle experiences the sum of the effects caused by the two MEs and effectively the induced gauge potentials sum up. This gives rise to a standing wave lasting for some time - that is scalar wave pulse. The effect is like that caused by scalar wave pulse and behaves effectively like massive particle. Pulse can carry charges since MEs can carry light-like current whose effects correspond to their sum - charge density but vanishing current in the rest system.

When scalar wave pulse moves in matter, charges end up to the space-time sheet of the scalar wave pulse and accelerate without dissipation. Instead of brehmstrahlung the accelerated charges emit negative energy "acceleration radiation" having negative energy MEs as space-time correlates. Since dissipation is negligible this leads to a generation of a strong negative energy signal. The resulting negative energy photons in turn induce the phase-transition like dropping of particles of population inverted many-sheeted laser to larger space-time sheets liberating a beam of positive energy photons which is much more intense than the control signal consisting of negative energy photons.

A good guess is that scalar wave pulses provide a fundamental control mechanism in living matter, and that nerve pulse represents only a special case of this control mechanism. p-Adic length scale hypothesis suggests the existence of a hierarchy of cognitive codes such that $p \simeq 2^k$, k integer, corresponds to a hierarchy of cognitive codes such that the code word has duration given by n-ary p-adic time scale $T(n,k)$, and the number of bits is a factor of k. These codes allow both pulse representations and frequency representations. For pulse representations bit 1/0 is represented by the presence/absence of scalar wave pulse. For frequency representations bit 1/0 would correspond to Fourier component with particular harmonic of fundamental frequency $f(n,k) = 1/T(n,k)$ above or below critical intensity. Pulse representations would be ideal for a precise bio-control whereas frequency representations might be ideal for communications of data from brain to magnetic body.

Intentions could be transformed also to actions by generation of magnetic flux tubes: so called wormhole magnetic fields correspond to pairs of magnetic flux tubes having opposite time orientations and therefore also opposite energies. Wormhole magnetic fields could be created by first generating their p-adic counterparts, and then transforming them to their real counterparts in quantum jump. The phase transition like changes of EEG spectrum involving emergence or dis-appearance of EEG band might be due to the generation of wormhole magnetic fields giving rise to EEG resonance frequencies via cyclotron transitions and thus represent motor actions of magnetic body [K37, K85]. Wormhole magnetic fields are discussed in detail in [K121].

9.1.3 Electrets And Scalar Waves Of Tesla

Living matter is full of electrets. Basic examples are micro-tubuli carrying a longitudinal electric field and cell membrane carrying a transversal electric field. One can see electret as a structure consisting of a topological field quantum of electric field plus atomic space-time sheets carrying ordinary bio-matter. Electrets carrying an electric field which has in a good approximation a constant magnitude, are indeed basic solutions of the field equations, and are in a well defined sense dual to the magnetic flux tubes. This duality reflects the fundamental duality of quantum TGD itself analogous to the duality of super string theories but having different physical content. Quantum criticality of TGD predicts that space-time sheets carrying electric field *resp.* magnetic fields with negative *resp.* positive Kähler action are like two phases, say water and ice, at the critical point. What is interesting is that electret type solutions contain as a special case electric pulses propagating with light velocity. These solutions are identifiable as TGD counterparts of Tesla's scalar waves having electric field in the direction of propagation. These solutions are not possible in Maxwell's electrodynamics. Bio-systems might use scalar waves for communication and control purposes. For instance, the generation of nerve pulse might induce scalar wave which in turn could induce nerve pulses and this could lead to a cascade of coherent neural firing. Second interesting aspect is that electret type solutions carry strong classical gravitational fields at their boundaries and the coupling of the classical gravitation to the field energy is given essentially by the square of CP_2 radius squared and is thus about 10^7 times stronger than the coupling of gravitons to the ordinary matter. Hence classical gravitation might be important for the functioning of living matter. The spin glass degeneracy broken only by classical gravitational energy suggests the same.

9.1.4 Ideas Related To Dark Matter And Living Matter

I ended up with the idea about quantization of Planck constant and the identification of dark matter as phase with a non-standard value of Planck constant after having learned about the work of Da Rocha and Nottale. After that ideas developed rapidly and led to a profound generalization of the notion of embedding space and the idea about dark matter as being responsible for the properties of living matter emerged.

Dark matter as a macroscopic quantum phase with gigantic Planck constant

D. Da Rocha and Laurent Nottale, the developer of Scale Relativity, have ended up with an highly interesting quantum theory like model for the evolution of astrophysical systems [E6] (I am grateful for Victor Christianto for informing me about the article). The model is simply Schrödinger equation with Planck constant $\hbar$ replaced with what might be called gravitational Planck constant

$$\hbar \quad \rightarrow \quad \hbar_{gr} = \frac{GmM}{v_0} \quad . \tag{9.1.1}$$

Here I have used units $\hbar = c = 1$. v_0 is a velocity parameter having the value $v_0 = 144.7 \pm .7$ km/s giving $v_0/c = 4.6 \times 10^{-4}$. The peak orbital velocity of stars in galactic halos is 142 ± 2 km/s whereas the average velocity is 156 ± 2 km/s. Also subharmonics and harmonics of v_0 seem to appear.

The model makes fascinating predictions which hold true. For instance, the radii of planetary orbits fit nicely with the prediction of the hydrogen atom like model. The inner solar system (planets up to Mars) corresponds to v_0 and outer solar system to $v_0/5$.

It is important to notice that effectively a multiplication $n \rightarrow 5n$ of the principal quantum number is in question in the case of outer planets. If one accepts the interpretation that visible matter has concentrated around dark matter, which is in macroscopic quantum phase around Bohr orbits, this allows to consider also the possibility that $\hbar_{gr}$ has same value for all planets.

1. Some external gravitational perturbations have kicked dark matter from inner orbits to $n\ mod\ 5 = 0$ orbits. Gravitational perturbations might have caused the same for visible matter. The fact that the tilt angles of Earth and outer planets other than Pluto are nearly the same suggests that the orbits of these planets might be an outcome of some violent quantum process for dark matter preserving the orbital plane in a good approximation but

kicking dark matter from $n = 5$ orbit of Earth to the orbits $n = 5k$, $k = 2, .., 7$. Pluto might in turn have experienced some violent collision changing its orbital plane.

2. There could exist at least small amounts of dark matter at all orbits but visible matter is concentrated only around orbits containing some critical amount of dark matter and these orbits satisfy $n = 5k$, $k = 2, 3, ...$ for some reason.

The predictions for the distribution of major axis and eccentricities have been tested successfully also for exo-planets. Also the periods of 3 planets around pulsar PSR B1257+12 fit with the predictions with a relative accuracy of few hours/per several months. Also predictions for the distribution of stars in the regions where morphogenesis occurs follow from the Schödinger equation.

What is important is that there are no free parameters besides v_0. In [E6] a wide variety of astrophysical data is discussed and it seem that the model works and has already now made predictions which have been later verified. A rather detailed model for the formation of solar system making quantitatively correct predictions follows from the study of inclinations and eccentricities predicted by the Bohr rules: the model proposed seems to differ from that of Nottale which makes predictions for the probability distribution of eccentricities and inclinations.

I had proposed already earlier the possibility that Planck constant is quantized. The inverse of the gravitational Planck constant could correspond a gravitational perturbation of this as $1/\hbar_{gr} = v_0/GMm$. The general philosophy would be that when the quantum system would become non-perturbative, a phase transition increasing the value of $\hbar$ occurs to preserve the perturbative character.

TGD predicts correctly the value of the parameter v_0 assuming that cosmic strings and their decay remnants are responsible for the dark matter. The harmonics of v_0 can be understood as corresponding to perturbations replacing cosmic strings with their n-branched coverings so that tension becomes n^2-fold: much like the replacement of a closed orbit with an orbit closing only after n turns. $1/n$-sub-harmonic would result when a magnetic flux tube split into n disjoint magnetic flux tubes.

The study of inclinations (tilt angles with respect to the Earth's orbital plane) leads to a concrete model for the quantum evolution of the planetary system. Only a stepwise breaking of the rotational symmetry and angular momentum Bohr rules plus Newton's equation (or geodesic equation) are needed, and gravitational Schrödinger equation holds true only inside flux quanta for the dark matter.

1. During pre-planetary period dark matter formed a quantum coherent state on the (Z^0) magnetic flux quanta (spherical cells or flux tubes). This made the flux quantum effectively a single rigid body with rotational degrees of freedom corresponding to a sphere or circle (full SO(3) or SO(2) symmetry).

2. In the case of spherical shells associated with inner planets the $SO(3) \to SO(2)$ symmetry breaking led to the generation of a flux tube with the inclination determined by m and j and a further symmetry breaking, kind of an astral traffic jam inside the flux tube, generated a planet moving inside flux tube. The semiclassical interpretation of the angular momentum algebra predicts the inclinations of the inner planets. The predicted (real) inclinations are 6 (7) resp. 2.6 (3.4) degrees for Mercury resp. Venus). The predicted (real) inclination of the Earth's spin axis is 24 (23.5) degrees.

3. The $v_0 \to v_0/5$ transition allowing to understand the radii of the outer planets in the model of Da Rocha and Nottale can be understood as resulting from the splitting of (Z^0) magnetic flux tube to five flux tubes representing Earth and outer planets except Pluto, whose orbital parameters indeed differ dramatically from those of other planets. The flux tube has a shape of a disk with a hole glued to the Earth's spherical flux shell.

It is important to notice that effectively a multiplication $n \to 5n$ of the principal quantum number is in question. This allows to consider also alternative explanations. Perhaps external gravitational perturbations have kicked dark matter from the orbit or Earth to $n = 5k$, $k = 2, 3, ..., 7$ orbits: the fact that the tilt angles for Earth and all outer planets except Pluto are nearly the same, supports this explanation. Or perhaps there exist at least small amounts of dark matter at all orbits but visible matter is concentrated only around orbits containing some critical amount of dark matter and these orbits satisfy $n \ mod \ 5 = 0$ for some reason.

The most interesting predictions from the point of view of living matter are following.

1. The dark matter is still there and forms quantum coherent structures of astrophysical size. In particular, the (Z^0) magnetic flux tubes associated with the planetary orbits define this kind of structures. The enormous value of h_{gr} makes the characteristic time scales of these quantum coherent states extremely long and implies macro-temporal quantum coherence in human and even longer time scales.

2. The rather amazing coincidences between basic bio-rhythms and the periods associated with the orbits in solar system suggest that the frequencies defined by the energy levels of the gravitational Schrödinger equation might entrain with various biological frequencies such as the cyclotron frequencies associated with the magnetic flux tubes. For instance, the period associated with $n = 1$ orbit in the case of Sun is 24 hours within experimental accuracy for v_0. Second example is the mysterious 5 second time scale associated with the Comorosan effect [I92, I33].

How the scaling of $\hbar$ affects physics and how to detect dark matter?

It is relatively easy to deduce the basic implications of the scaling of $\hbar$.

1. If the rate for the process is non-vanishing classically, it is not affected in the lowest order. For instance, scattering cross sections for say electron-electron scattering and e^+e^- annihilation are not affected in the lowest order since the increase of Compton length compensates for the reduction of α_{em}. Photon-photon scattering cross section, which vanishes classically and is proportional to $\alpha_{em}^4\hbar^2/E^2$, scales down as $1/\hbar^2$.

2. Higher order corrections coming as powers of the gauge coupling strength α are reduced since $\alpha = g^2/4\pi\hbar$ is reduced. Since one has $\hbar_s/\hbar = \alpha Q_1Q_2/v_0$, αQ_1Q_2 is effectively replaced with a universal coupling strength v_0. In the case of QCD the paradoxical sounding implication is that α_s would become very small.

Dark matter as quantum controller of ordinary matter

The notion of magnetic body containing macroscopic quantum phases responsible for bio-control, and the fact that dark matter would reside at magnetic flux tubes, motivate the hypothesis that living matter is actually dark matter with the large value of Planck constant determining the characteristic time and length scales of the conscious system. Complex conformal weights for single particles states and closely related to the zeros of Riemann Zeta would make the many-particle system living. p-Adic fractality allows to deduce rather striking similarities between biology, cosmology, and hadron physics.

One important implication is the possibility to relate the hierarchy of the time scales of consciousness defined by the effective durations of quantum jumps to the hierarchy of Planck constants. A beautiful mathematical formulation in terms of von Neumann algebras [A23, A18] as a hierarchy of quantum states emerges [K118]. The lowest level states represents ordinary matter whereas higher levels provide self representations of the dynamics of the system with S-matrix coding for the quantum physical laws represented as entanglement coefficients between positive and negative energy states forming states with vanishing net quantum numbers. The general construction of S-matrix gives also the Feynman rules for self representations and means a precise formulation of the quantum dynamics of cognition.

A refinement to the previously developed model of cold fusion [K97, K36] results in terms of a phase transition increasing the Compton length of protons and explains the known strange violations of standard nuclear physics rules [C8]. Sono-fusion [C14] can be seen as a special case of cold fusion. The fact that nuclear transmutations are reported to occur in living matter [C5] suggests that this phase might be important for living matter. Also the claimed properties of so called mono-atomic elements [H9] fit nicely with an interpretation as “partially dark” matter.

To sum up, the riddle of life, the riddle of dark matter, and the mysterious ability of living matter to behave like macroscopic quantum system despite the fact that ordinary quantum physics does not allow this, might have common very simple solution: $\hbar$ is dynamical rather than God given.

It must be added that the ideas about dark matter emerged about decade later than the first version of this chapter was written. I have not seen sensible to try to insert the dark matter related ideas to the existing text and this means that the representation is somewhat lopsided and partially out of date and should be taken as a documentary about how ideas have developed rather than a final summary.

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` [L13].

9.2 Preferred Extremals Of Kähler Action, Second Law Of Thermodynamics, And Bio-systems

In this section field equations and their physical interpretation and relevance for bio-systems are discussed. Quantum classical correspondence suggests that the non-deterministic dynamics of Kähler action makes possible self-referential dynamics in the sense that larger space-time sheet perform smoothed out mimicry of the dynamics at smaller space-time sheets. The fact that the divergence of the energy momentum tensor, Lorentz 4-force, does not vanish in general makes possible the mimicry of even dissipation and of the second law. For asymptotic self organization patterns for which dissipation is absent the Lorentz 4-force must vanish. This condition is guaranteed if Kähler current is proportional to the instanton current in the case that CP_2 projection of the space-time sheet is smaller than four and vanishes otherwise. An attractive identification for the vanishing of Lorentz 4-force is as a condition equivalent with preferred extremal property of Kähler action. In General Relativity this condition means vanishing of covariant divergence of energy momentum tensor leading to Einstein's equations.

What preferred extremal property means is however not at all obvious. Absolute minimization of Kähler action was the first guess. The notion of absolute minimization does not however make sense in p-adic context unless one manages to reduce it to purely algebraic conditions. Therefore it is better to talk just about preferred extremals of Kähler action and accept as the fact that there are several proposals for what this notion could mean. For instance, one can consider the identification of space-time surface as quaternionic sub-manifold meaning that tangent space of space-time surface can be regarded as quaternionic sub-manifold of complexified octonions defining tangent space of embedding space. One manner to define "quaternionic sub-manifold" is by introducing octonionic representation of embedding space gamma matrices identified as tangent space vectors. It must be also assumed that the tangent space contains a preferred complex (commutative) sub-space at each point and defining an integrable distribution having identification as string world sheet (also slicing of space-time sheet by string world sheets can be considered). Associativity and commutativity would define the basic dynamical principle. A closely related approach is based on so called Hamilton-Jacobi structure [K16] defining also this kind of slicing and the approaches could be equivalent. A further approach is based on the identification of preferred extremal property as quantum criticality [K16].

For a vanishing Kähler electric field the topologication of the Kähler current means that Kähler magnetic field is so called Beltrami field, that is an eigen vector of curl operator so that field pattern is typically helical unless the Kähler current vanishes. Beltrami field is characterized by a chirality defined by the relative sign of the current and magnetic field, which means parity breaking. Beltrami fields appear in hydrodynamics and magnetohydrodynamics, and a natural guess is that many-sheeted magnetic and Z^0 magnetic Beltrami fields and their generalizations serve as templates for the helical molecules populating living matter and explain both chirality selection and complex linking and knotting of DNA and protein molecules.

9.2.1 Field Equations

The requirement that Kähler action is stationary leads to the following field equations in the interior of the four-surface

$$\begin{aligned} D_\beta(T^{\alpha\beta}h^k_\alpha) &- j^\alpha J_\alpha^{\ \beta} J^k_{\ l}\partial_\beta h^l = 0 \ , \\ T^{\alpha\beta} &= J^{\nu\alpha}J_\nu^{\ \beta} - \frac{1}{4}g^{\alpha\beta}J^{\mu\nu}J_{\mu\nu} \ . \end{aligned} \tag{9.2.1}$$

Here $T^{\alpha\beta}$ denotes the traceless canonical energy momentum tensor associated with the Kähler action. An equivalent form for the first equation is

$$\begin{aligned} T^{\alpha\beta}H^k_{\alpha\beta} &+ j^\alpha(J_\alpha^{\ \beta}h^k_{\ l} - J^k_{\ l}\partial_\alpha h^l) = 0 \ . \\ H^k_{\alpha\beta} &= D_\beta\partial_\alpha h^k \ . \end{aligned} \tag{9.2.2}$$

$H^k_{\alpha\beta}$ denotes the components of the second fundamental form and $j^\alpha = D_\beta J^{\alpha\beta}$ is the gauge current associated with the Kähler field.

On the boundaries of X^4 the field equations are given by the expression

$$T^{n\beta}\partial_\beta h^k + J^{n\alpha}(J_\alpha^{\ \beta}\partial_\beta h^k - J^k_{\ l})\partial_\alpha h^k) = 0 \ . \tag{9.2.3}$$

A general manner manner to solve the field equations on the boundaries is to assume that the induced Kähler field associated with the boundaries vanishes:

$$J_{\alpha\beta}(\delta) \ = \ 0 \ . \tag{9.2.4}$$

In this case the energy-momentum tensor vanishes identically on the boundary component. On the outer boundaries of the 3-surface this solution ansatz makes sense only provided the gauge fluxes and gravitational flux (defined by Newtonian potential in the non-relativistic limit) associated with the matter in the interior go somewhere. The only possibility seems to be that 3-surface is topologically condensed on a larger 3-surface and feeds its gauge fluxes to the larger 3-surface via # contacts (topological sum). This assumption forces the concept of topological condensate defined as a hierarchical structure of 3-surfaces condensed on each other and thus giving rise to the many-sheeted space-time.

An important thing to notice is that the boundary conditions do not force the normal components of the gauge fields to zero even if the Kähler electric field vanishes near the boundaries. This makes in principle possible gauge charge renormalization classically resulting from the hierarchical structure of the topological condensation.

9.2.2 Topologization And Light-Likeness Of The Kähler Current As Alternative ways To Guarantee Vanishing Of Lorentz 4-Force

The general solution of 4-dimensional Einstein-Yang Mills equations in Euclidian 4-metric relies on self-duality of the gauge field, which topologizes gauge charge. This topologization can be achieved by a weaker condition, which can be regarded as a dynamical generalization of the Beltrami condition. An alternative manner to achieve vanishing of the Lorentz 4-force is light-likeness of the Kähler 4-current. This does not require topologization.

Topologization of the Kähler current for $D_{CP_2} = 3$: covariant formulation

The condition states that Kähler 4-current is proportional to the instanton current whose divergence is instanton density and vanishes when the dimension of CP_2 projection is smaller than four: $D_{CP_2} < 4$. For $D_{CP_2} = 2$ the instanton 4-current vanishes identically and topologization is equivalent with the vanishing of the Kähler current.

$$j^\alpha \equiv D_\beta J^{\alpha\beta} \ = \ \psi \times j_I^\alpha = \psi \times \epsilon^{\alpha\beta\gamma\delta}J_{\beta\gamma}A_\delta \ . \tag{9.2.5}$$

Here the function ψ is an arbitrary function $\psi(s^k)$ of CP_2 coordinates s^k regarded as functions of space-time coordinates. It is essential that ψ depends on the space-time coordinates through the CP_2 coordinates only. Hence the representation as an imbedded gauge field is crucial element of the solution ansatz.

The field equations state the vanishing of the divergence of the 4-current. This is trivially true for instanton current for $D_{CP_2} < 4$. Also the contraction of $\nabla\psi$ (depending on space-time coordinates through CP_2 coordinates only) with the instanton current is proportional to the winding number density and therefore vanishes for $D_{CP_2} < 4$.

The topologization of the Kähler current guarantees the vanishing of the Lorentz 4-force. Indeed, using the self-duality condition for the current, the expression for the Lorentz 4-force reduces to a term proportional to the instanton density:

$$\begin{aligned} j^{\alpha}J_{\alpha\beta} &= \psi \times j^{\alpha}_I J_{\alpha\beta} \\ &= \psi \times \epsilon^{\alpha\mu\nu\delta}J_{\mu\nu}A_{\delta}J_{\alpha\beta} \ . \end{aligned} \tag{9.2.6}$$

Since all vector quantities appearing in the contraction with the four-dimensional permutation tensor are proportional to the gradients of CP_2 coordinates, the expression is proportional to the instanton density, and thus winding number density, and vanishes for $D_{CP_2} < 4$.

Remarkably, the topologization of the Kähler current guarantees also the vanishing of the term $j^{\alpha}J^{k_l}\partial_{\alpha}s^k$ in the field equations for CP_2 coordinates. This means that field equations reduce in both M^4_+ and CP_2 degrees of freedom to

$$T^{\alpha\beta}H^k_{\alpha\beta} = 0 \ . \tag{9.2.7}$$

These equations differ from the equations of minimal surface only by the replacement of the metric tensor with energy momentum tensor. The earlier proposal that quaternion conformal invariance in a suitable sense might provide a general solution of the field equations could be seen as a generalization of the ordinary conformal invariance of string models. If the topologization of the Kähler current implying effective dimensional reduction in CP_2 degrees of freedom is consistent with quaternion conformal invariance, the quaternion conformal structures must differ for the different dimensions of CP_2 projection.

Topologization of the Kähler current for $D_{CP_2} = 3$: non-covariant formulation

In order to gain a concrete understanding about what is involved it is useful to repeat these arguments using the 3-dimensional notation. The components of the instanton 4-current read in three-dimensional notation as

$$\overline{j}_I = \overline{E}\times\overline{A} + \phi\overline{B} \ , \quad \rho_I = \overline{B}\cdot\overline{A} \ . \tag{9.2.8}$$

The self duality conditions for the current can be written explicitly using 3-dimensional notation and read

$$\begin{aligned} \nabla\times\overline{B} - \partial_t\overline{E} &= \overline{j} = \psi\overline{j}_I = \psi\left(\phi\overline{B} + \overline{E}\times\overline{A}\right) \ , \\ \nabla\cdot E &= \rho = \psi\rho_I \ . \end{aligned} \tag{9.2.9}$$

For a vanishing electric field the self-duality condition for Kähler current reduces to the Beltrami condition

$$\nabla\times\overline{B} = \alpha\overline{B} \ , \quad \alpha = \psi\phi \ . \tag{9.2.10}$$

The vanishing of the divergence of the magnetic field implies that α is constant along the field lines of the flow. When ϕ is constant and $\overline{A}$ is time independent, the condition reduces to the Beltrami condition with $\alpha = \phi = constant$, which allows an explicit solution [B6].

One can check also the vanishing of the Lorentz 4-force by using 3-dimensional notation. Lorentz 3-force can be written as

$$\rho_I\overline{E}+\overline{j}\times\overline{B}=\psi\overline{B}\cdot\overline{AE}+\psi\left(\overline{E}\times\overline{A}+\phi\overline{B}\right)\times\overline{B}=0\ . \qquad (9.2.11)$$

The fourth component of the Lorentz force reads as

$$\overline{j}\cdot\overline{E}=\psi\overline{B}\cdot\overline{E}+\psi\left(\overline{E}\times\overline{A}+\phi\overline{B}\right)\cdot\overline{E}=0\ . \qquad (9.2.12)$$

The remaining conditions come from the induction law of Faraday and could be guaranteed by expressing $\overline{E}$ and $\overline{B}$ in terms of scalar and vector potentials.

The density of the Kähler electric charge of the vacuum is proportional to the the helicity density of the so called helicity charge $\rho=\psi\rho_I=\psi B\cdot A$. This charge is topological charge in the sense that it does not depend on the induced metric at all. Note the presence of arbitrary function ψ of CP_2 coordinates.

Further conditions on the functions appearing in the solution ansatz come from the 3 independent field equations for CP_2 coordinates. What is remarkable that the generalized self-duality condition for the Kähler current allows to understand the general features of the solution ansatz to very high degree without any detailed knowledge about the detailed solution. The question whether field equations allow solutions consistent with the self duality conditions of the current will be dealt later. The optimistic guess is that the field equations and topologization of the Kähler current relate to each other very intimately.

Vanishing or light likeness of the Kähler current guarantees vanishing of the Lorentz 4-force for $D_{CP_2}=2$

For $D_{CP_2}=2$ one can always take two CP_2 coordinates as space-time coordinates and from this it is clear that instanton current vanishes so that topologization gives a vanishing Kähler current. In particular, the Beltrami condition $\nabla\times\overline{B}=\alpha\overline{B}$ is not consistent with the topologization of the instanton current for $D_{CP_2}=2$.

$D_{CP_2}=2$ case can be treated in a coordinate invariant manner by using the two coordinates of CP_2 projection as space-time coordinates so that only a magnetic or electric field is present depending on whether the gauge current is time-like or space-like. Light-likeness of the gauge current provides a second manner to achieve the vanishing of the Lorentz force and is realized in case of massless extremals having $D_{CP_2}=2$: this current is in the direction of propagation whereas magnetic and electric fields are orthogonal to it so that Beltrami conditions is certainly not satisfied.

Under what conditions topologization of Kähler current yields Beltrami conditions?

Topologization of the Kähler 4-current gives rise to magnetic Beltrami fields if either of the following conditions is satisfied.

1. The $\overline{E}\times\overline{A}$ term contributing besides $\phi\overline{B}$ term to the topological current vanishes. This requires that $\overline{E}$ and $\overline{A}$ are parallel to each other

$$\overline{E}\ =\ \nabla\Phi-\partial_t\overline{A}=\beta\overline{A} \qquad (9.2.13)$$

   This condition is analogous to the Beltrami condition. Now only the 3-space has as its coordinates time coordinate and two spatial coordinatesand$\overline{B}$ is replaced with $\overline{A}$. Since E and B are orthogonal, this condition implies $\overline{B}\cdot\overline{A}=0$ so that Kähler charge density is vanishing.

2. The vector $\overline{E}\times\overline{A}$ is parallel to $\overline{B}$.

$$\overline{E}\times\overline{A} \quad = \quad \beta\overline{B} \tag{9.2.14}$$

The condition is consistent with the orthogonality of $\overline{E}$ and $\overline{B}$ but implies the orthogonality of $\overline{A}$ and $\overline{B}$ so that electric charge density vanishes

In both cases vector potential fails to define a contact structure since $B\cdot A$ vanishes (contact structures are discussed briefly below), and there exists a global coordinate along the field lines of $\overline{A}$ and the full contact structure is lost again. Note however that the Beltrami condition for magnetic field means that magnetic field defines a contact structure irrespective of whether $\overline{B}\cdot\overline{A}$ vanishes or not. The transition from the general case to Beltrami field would thus involve the replacement

$$(\overline{A},\overline{B}) \rightarrow_{\nabla\times} (\overline{B},\overline{j})$$

induced by the rotor.

One must of course take these considerations somewhat cautiously since the inner product depends on the induced 4-metric and it might be that induced metric could allow small vacuum charge density and make possible genuine contact structure.

Hydrodynamic analogy

The field equations of TGD are basically hydrodynamic equations stating the local conservation of the currents associated with the isometries of the embedding space. Therefore it is intriguing that Beltrami fields appear also as solutions of ideal magnetohydrodynamics equations and as steady solutions of non-viscous incompressible flow described by Euler equations [B18].

In hydrodynamics the role of the magnetic field is taken by the velocity field. For incompressible flow occurring along the field lines of the Z^0 magnetic field the velocity field is proportional to the Z^0 magnetic field and the Beltrami condition for the velocity field reduces to that for Z^0 magnetic field. Thus the flow lines of hydrodynamic flow should directly correspond to those of Z^0 magnetic field. The generalized Beltrami flow based on the topologization of the Z^0 current would allow to model also the non-stationary incompressible non-viscous hydrodynamical flows.

It would seem that one cannot describe viscous flows using flows satisfying generalized Beltrami conditions since the vanishing of the Lorentz 4-force says that there is no local dissipation of the classical field energy. One might claim that this is not a problem since in TGD framework viscous flow could be seen as a practical description of a quantum jump sequence by replacing the corresponding sequence of space-time surfaces with a single space-time surface.

One the other hand, quantum classical correspondence requires that also dissipative effects have space-time correlates. Kähler fields, which are dissipative, and thus correspond to a non-vanishing Lorentz 4-force, represent one candidate for correlates of this kind. If this is the case, then the fields satisfying the generalized Beltrami condition provide space-time correlates only for the asymptotic self organization patterns for which the viscous effects are negligible, and also the solutions of field equations describing effects of viscosity should be possible.

One must however take this argument with a grain of salt. Dissipation, that is the transfer of conserved quantities to degrees of freedom corresponding to shorter scales, could correspond to a transfer of these quantities between different space-time sheets of the many-sheeted space-time. Here the opponent could however argue that larger space-time sheets mimic the dissipative dynamics in shorter scales and that classical currents represent “symbolically” averaged currents in shorter length scales, and that the local non-conservation of energy momentum tensor consistent with local conservation of isometry currents provides a unique manner to mimic the dissipative dynamics. This view will be developed in more detail below.

The stability of generalized Beltrami fields

The stability of generalized Beltrami fields is of high interest since unstable points of space-time sheets are those around which macroscopic changes induced by quantum jumps are expected to be localized.

1. Contact forms and contact structures

The stability of Beltrami flows has been studied using the theory of contact forms in three-dimensional Riemann manifolds [B17]. Contact form is a one-form A (that is covariant vector field A_α) with the property $A \wedge dA \neq 0$. In the recent case the induced Kähler gauge potential A_α and corresponding induced Kähler form $J_{\alpha\beta}$ for any 3-sub-manifold of space-time surface define a contact form so that the vector field $A^\alpha = g^{\alpha\beta} A_\beta$ is not orthogonal with the magnetic field $B^\alpha = \epsilon^{\alpha\beta\delta} J_{\beta\gamma}$. This requires that magnetic field has a helical structure. Induced metric in turn defines the Riemann structure.

If the vector potential defines a contact form, the charge density associated with the topologized Kähler current must be non-vanishing. This can be seen as follows.

1. The requirement that the flow lines of a one-form X_μ defined by the vector field X^μ as its dual allows to define a global coordinate x varying along the flow lines implies that there is an integrating factor ϕ such that $\phi X = dx$ and therefore $d(\phi X) = 0$. This implies $dlog(\phi) \wedge X = -dX$. From this the necessary condition for the existence of the coordinate x is $X \wedge dX = 0$. In the three-dimensional case this gives $\overline{X} \cdot (\nabla \times \overline{X}) = 0$.

2. This condition is by definition not satisfied by the vector potential defining a contact form so that one cannot identify a global coordinate varying along the flow lines of the vector potential. The condition $\overline{B} \cdot \overline{A} \neq 0$ states that the charge density for the topologized Kähler current is non-vanishing. The condition that the field lines of the magnetic field allow a global coordinate requires $\overline{B} \cdot \nabla \times \overline{B} = 0$. The condition is not satisfied by Beltrami fields with $\alpha \neq 0$. Note that in this case magnetic field defines a contact structure.

Contact structure requires the existence of a vector ξ satisfying the condition $A(\xi) = 0$. The vector field ξ defines a plane field, which is orthogonal to the vector field A^α. Reeb field in turn is a vector field for which $A(X) = 1$ and $dA(X;) = 0$ hold true. The latter condition states the vanishing of the cross product $X \times B$ so that X is parallel to the Kähler magnetic field B^α and has unit projection in the direction of the vector field A^α. Any Beltrami field defines a Reeb field irrespective of the Riemannian structure.

2. Stability of the Beltrami flow and contact structures

Contact structures are used in the study of the topology and stability of the hydrodynamical flows [B17], and one might expect that the notion of contact structure and its proper generalization to the four-dimensional context could be useful in TGD framework also. An example giving some idea about the complexity of the flows defined by Beltrami fields is the Beltrami field in R^3 possessing closed orbits with all possible knot and link types simultaneously [B17] !

Beltrami flows associated with Euler equations are known to be unstable [B17]. Since the flow is volume preserving, the stationary points of the Beltrami flow are saddle points at which also vorticity vanishes and linear instabilities of Navier-Stokes equations can develop. From the point of view of biology it is interesting that the flow is stabilized by vorticity which implies also helical structures. The stationary points of the Beltrami flow correspond in TGD framework to points at which the induced Kähler magnetic field vanishes. They can be unstable by the vacuum degeneracy of Kähler action implying classical non-determinism. For generalized Beltrami fields velocity and vorticity (both divergence free) are replaced by Kähler current and instanton current.

More generally, the points at which the Kähler 4-current vanishes are expected to represent potential instabilities. The instanton current is linear in Kähler field and can vanish in a gauge invariant manner only if the induced Kähler field vanishes so that the instability would be due to the vacuum degeneracy also now. Note that the vanishing of the Kähler current allows also the generation of region with $D_{CP_2} = 4$. The instability of the points at which induce Kähler field vanish is manifested in quantum jumps replacing the generalized Beltrami field with a new one such that something new is generated around unstable points. Thus the regions in which induced

Kähler field becomes weak are the most interesting ones. For example, unwinding of DNA could be initiated by an instability of this kind.

9.2.3 How To Satisfy Field Equations?

The topologization of the Kähler current guarantees also the vanishing of the term $j^{\alpha}J^{k_l}\partial_{\alpha}s^k$ in the field equations for CP_2 coordinates. This means that field equations reduce in both M^4_+ and CP_2 degrees of freedom to

$$T^{\alpha\beta}H^k_{\alpha\beta} = 0 \ . \quad (9.2.15)$$

These equations differ from the equations of minimal surface only by the replacement of the metric tensor with energy momentum tensor. The earlier proposal that quaternion conformal invariance in a suitable sense might provide a general solution of the field equations could be seen as a generalization of the ordinary conformal invariance of string models. If the topologization of the Kähler current implying effective dimensional reduction in CP_2 degrees of freedom is consistent with quaternion conformal invariance, the quaternion conformal structures must differ for the different dimensions of CP_2 projection. In the following somewhat different approach is however considered utilizing the properties of Hamilton Jacobi structures of M^4_+ introduced in the study of massless extremals and contact structures of CP_2 emerging naturally in the case of generalized Beltrami fields.

String model as a starting point

String model serves as a starting point.

1. In the case of Minkowskian minimal surfaces representing string orbit the field equations reduce to purely algebraic conditions in light cone coordinates (u,v) since the induced metric has only the component g_{uv}, whereas the second fundamental form has only diagonal components H^k_{uu} and H^k_{vv}.

2. For Euclidian minimal surfaces (u,v) is replaced by complex coordinates $(w,\overline{w})$ and field equations are satisfied because the metric has only the component $g^{w\overline{w}}$ and second fundamental form has only components of type H^k_{ww} and $H^{\overline{k}}_{\overline{ww}}$. The mechanism should generalize to the recent case.

The general form of energy momentum tensor as a guideline for the choice of coordinates

Any 3-dimensional Riemann manifold allows always a orthogonal coordinate system for which the metric is diagonal. Any 4-dimensional Riemann manifold in turn allows a coordinate system for which 3-metric is diagonal and the only non-diagonal components of the metric are of form g^{ti}. This kind of coordinates might be natural also now. When $\overline{E}$ and $\overline{B}$ are orthogonal, energy momentum tensor has the form

$$T = \begin{pmatrix} \frac{E^2+B^2}{2} & 0 & 0 & EB \\ 0 & \frac{E^2+B^2}{2} & 0 & 0 \\ 0 & 0 & \frac{-E^2+B^2}{2} & 0 \\ EB & 0 & 0 & \frac{E^2-B^2}{2} \end{pmatrix} \quad (9.2.16)$$

in the tangent space basis defined by time direction and longitudinal direction $\overline{E}\times\overline{B}$, and transversal directions $\overline{E}$ and $\overline{B}$. Note that T is traceless.

The optimistic guess would be that the directions defined by these vectors integrate to three orthogonal coordinates of X^4 and together with time coordinate define a coordinate system containing only g^{ti} as non-diagonal components of the metric. This however requires that the fields in question allow an integrating factor and, as already found, this requires $\nabla\times X\cdot X = 0$ and this is not the case in general.

Physical intuition suggests however that X^4 coordinates allow a decomposition into longitudinal and transversal degrees freedom. This would mean the existence of a time coordinate t and longitudinal coordinate z the plane defined by time coordinate and vector $\overline{E} \times \overline{B}$ such that the coordinates $u = t - z$ and $v = t + z$ are light like coordinates so that the induced metric would have only the component g^{uv} whereas g^{vv} and g^{uu} would vanish in these coordinates. In the transversal space-time directions complex space-time coordinate coordinate w could be introduced. Metric could have also non-diagonal components besides the components $g^{w\overline{w}}$ and g^{uv}.

Hamilton Jacobi structures in M^4_+

Hamilton Jacobi structure in M^4_+ can understood as a generalized complex structure combing transversal complex structure and longitudinal hyper-complex structure so that notion of holomorphy and Kähler structure generalize.

1. Denote by m^i the linear Minkowski coordinates of M^4. Let (S^+, S^-, E^1, E^2) denote local coordinates of M^4_+ defining a *local* decomposition of the tangent space M^4 of M^4_+ into a direct, not necessarily orthogonal, sum $M^4 = M^2 \oplus E^2$ of spaces M^2 and E^2. This decomposition has an interpretation in terms of the longitudinal and transversal degrees of freedom defined by local light-like four-velocities $v_\pm = \nabla S_\pm$ and polarization vectors $\epsilon_i = \nabla E_i$ assignable to light ray. Assume that E^2 allows complex coordinates $w = E^1 + iE^2$ and $\overline{w} = E^1 - iE^2$. The simplest decomposition of this kind corresponds to the decomposition $(S^+ \equiv u = t + z, S^- \equiv v = t - z, w = x + iy, \overline{w} = x - iy)$.

2. In accordance with this physical picture, S^+ and S^- define light-like curves which are normals to light-like surfaces and thus satisfy the equation:

   $$(\nabla S_\pm)^2 = 0 \quad .$$

   The gradients of $S_\pm$ are obviously analogous to local light like velocity vectors $v = (1, \overline{v})$ and $\tilde{v} = (1, -\overline{v})$. These equations are also obtained in geometric optics from Hamilton Jacobi equation by replacing photon's four-velocity with the gradient ∇S: this is consistent with the interpretation of massless extremals as Bohr orbits of em field. $S_\pm = constant$ surfaces can be interpreted as expanding light fronts. The interpretation of $S_\pm$ as Hamilton Jacobi functions justifies the term Hamilton Jacobi structure.

   The simplest surfaces of this kind correspond to $t = z$ and $t = -z$ light fronts which are planes. They are dual to each other by hyper complex conjugation $u = t - z \rightarrow v = t + z$. One should somehow generalize this conjugation operation. The simplest candidate for the conjugation $S^+ \rightarrow S^-$ is as a conjugation induced by the conjugation for the arguments: $S^+(t - z, t + z, x, y) \rightarrow S^-(t - z, t + z, x, y) = S^+(t + z, t - z, x, -y)$ so that a dual pair is mapped to a dual pair. In transversal degrees of freedom complex conjugation would be involved.

3. The coordinates $(S_\pm, w, \overline{w})$ define local light cone coordinates with the line element having the form

   $$\begin{aligned} ds^2 &= g_{+-}dS^+dS^- + g_{w\overline{w}}dwd\overline{w} \\ &+ g_{+w}dS^+dw + g_{+\overline{w}}dS^+d\overline{w} \\ &+ g_{-w}dS^-dw + g_{-\overline{w}}dS^-d\overline{w} \quad . \end{aligned} \tag{9.2.17}$$

   Conformal transformations of M^4_+ leave the general form of this decomposition invariant. Also the transformations which reduces to analytic transformations $w \rightarrow f(w)$ in transversal degrees of freedom and hyper-analytic transformations $S^+ \rightarrow f(S^+), S^- \rightarrow f(S^-)$ in longitudinal degrees of freedom preserve this structure.

4. The basic idea is that of generalized Kähler structure meaning that the notion of Kähler function generalizes so that the non-vanishing components of metric are expressible as

$$\begin{aligned} g_{w\overline{w}} &= \partial_w \partial_{\overline{w}} K \ , \quad g_{+-} = \partial_{S^+} \partial_{S^-} K \ , \\ g_{w\pm} &= \partial_w \partial_{S^\pm} K \ , \quad g_{\overline{w}\pm} = \partial_{\overline{w}} \partial_{S^\pm} K \ . \end{aligned} \tag{9.2.18}$$

for the components of the metric. The expression in terms of Kähler function is coordinate invariant for the same reason as in case of ordinary Kähler metric. In the standard light-cone coordinates the Kähler function is given by

$$K = w_0 \overline{w}_0 + uv \ , \quad w_0 = x + iy \ , \quad u = t - z \ , \quad v = t + z \ . \tag{9.2.19}$$

The Christoffel symbols satisfy the conditions

$$\{ {}_{w}^{k} {}_{\overline{w}} \} = 0 \ , \quad \{ {}_{+-}^{\ k} \} = 0 \ . \tag{9.2.20}$$

If energy momentum tensor has only the components $T^{w\overline{w}}$ and T^{+-}, field equations are satisfied in M^4_+ degrees of freedom.

5. The Hamilton Jacobi structures related by these transformations can be regarded as being equivalent. Since light-like 3- surface is, as the dynamical evolution defined by the light front, fixed by the 2-surface serving as the light source, these structures should be in one-one correspondence with 2-dimensional surfaces with two surfaces regarded as equivalent if they correspond to different time=constant snapshots of the same light front, or are related by a conformal transformation of M^4_+. Obviously there should be quite large number of them. Note that the generating two-dimensional surfaces relate also naturally to quaternion conformal invariance and corresponding Kac Moody invariance for which deformations defined by the M^4 coordinates as functions of the light-cone coordinates of the light front evolution define Kac Moody algebra, which thus seems to appear naturally also at the level of solutions of field equations.

The task is to find all possible local light cone coordinates defining one-parameter families 2-surfaces defined by the condition $S_i = constant$, $i = +\ or\ \ = -$, dual to each other and expanding with light velocity. The basic open questions are whether the generalized Kähler function indeed makes sense and whether the physical intuition about 2-surfaces as light sources parameterizing the set of all possible Hamilton Jacobi structures makes sense.

Contact structure and generalized Kähler structure of CP_2 projection

In the case of 3-dimensional CP_2 projection it is assumed that one can introduce complex coordinates $(\xi, \overline{\xi})$ and the third coordinate s. These coordinates would correspond to a contact structure in 3-dimensional CP_2 projection defining transversal symplectic and Kähler structures. In these coordinates the transversal parts of the induced CP_2 Kähler form and metric would contain only components of type $g_{w\overline{w}}$ and $J_{w\overline{w}}$. The transversal Kähler field $J_{w\overline{w}}$ would induce the Kähler magnetic field and the components J_{sw} and $J_{s\overline{w}}$ the Kähler electric field.

It must be emphasized that the non-integrability of the contact structure implies that J cannot be parallel to the tangent planes of $s = constant$ surfaces, s cannot be parallel to neither A nor the dual of J, and ξ cannot vary in the tangent plane defined by J. A further important conclusion is that for the solutions with 3-dimensional CP_2 projection topologized Kähler charge density is necessarily non-vanishing by $A \wedge J \neq 0$ whereas for the solutions with $D_{CP_2} = 2$ topologized Kähler current vanishes.

Also the CP_2 projection is assumed to possess a generalized Kähler structure in the sense that all components of the metric except s_{ss} are derivable from a Kähler function by formulas similar to M^4_+ case.

$$s_{w\overline{w}} = \partial_w \partial_{\overline{w}} K \ , \quad s_{ws} = \partial_w \partial_s K \ , \quad s_{\overline{w}s} = \partial_{\overline{w}} \partial_s K \ . \tag{9.2.21}$$

Generalized Kähler property guarantees that the vanishing of the Christoffel symbols of CP_2 (rather than those of 3-dimensional projection), which are of type $\{{}^{\ k}_{\xi\ \overline{\xi}}\}$.

$$\{{}^{\ k}_{\xi\ \overline{\xi}}\} \ = \ 0 \ . \tag{9.2.22}$$

Here the coordinates of CP_2 have been chosen in such a manner that three of them correspond to the coordinates of the projection and fourth coordinate is constant at the projection. The upper index k refers also to the CP_2 coordinate, which is constant for the CP_2 projection. If energy momentum tensor has only components of type T^{+-} and $T^{w\overline{w}}$, field equations are satisfied even when if non-diagonal Christoffel symbols of CP_2 are present. The challenge is to discover solution ansatz, which guarantees this property of the energy momentum tensor.

A stronger variant of Kähler property would be that also s_{ss} vanishes so that the coordinate lines defined by s would define light like curves in CP_2. The topologization of the Kähler current however implies that CP_2 projection is a projection of a 3-surface with strong Kähler property. Using $(s, \xi, \overline{\xi}, S^-)$ as coordinates for the space-time surface defined by the ansatz $(w = w(\xi, s), S^+ = S^+(s))$ one finds that g_{ss} must be vanishing so that stronger variant of the Kähler property holds true for $S^- = constant$ 3-surfaces.

The topologization condition for the Kähler current can be solved completely generally in terms of the induced metric using $(\xi, \overline{\xi}, s)$ and some coordinate of M^4_+, call it x^4, as space-time coordinates. Topologization boils down to the conditions

$$\begin{aligned} \partial_\beta (J^{\alpha\beta}\sqrt{g}) \ &= \ 0 \text{ for } \ \alpha \in \{\xi, \overline{\xi}, s\} \ , \\ g^{4i} &\neq 0 \ . \end{aligned} \tag{9.2.23}$$

Thus 3-dimensional empty space Maxwell equations and the non-orthogonality of x^4 coordinate lines and the 3-surfaces defined by the lift of the CP_2 projection.

A solution ansatz yielding light-like current in $D_{CP_2} = 3$ case

The basic idea is that of generalized Kähler structure and solutions of field equations as maps or deformations of canonically imbedded M^4_+ respecting this structure and guaranteeing that the only non-vanishing components of the energy momentum tensor are $T^{\xi\xi}$ and T^{s-} in the coordinates $(\xi, \overline{\xi}, s, S^-)$.

1. The coordinates (w, S^+) are assumed to holomorphic functions of the CP_2 coordinates (s, ξ)

$$S^+ = S^+(s) \ , \quad w = w(\xi, s) \ . \tag{9.2.24}$$

   Obviously S^+ could be replaced with S^-. The ansatz is completely symmetric with respect to the exchange of the roles of (s, w) and (S^+, ξ) since it maps longitudinal degrees of freedom to longitudinal ones and transverse degrees of freedom to transverse ones.

2. Field equations are satisfied if the only non-vanishing components of the energy momentum tensor are of type $T^{\xi\overline{\xi}}$ and T^{s-}. The reason is that the CP_2 Christoffel symbols for projection and projections of M^4_+ Christoffel symbols are vanishing for these lower index pairs.

3. By a straightforward calculation one can verify that the only manner to achieve the required structure of energy momentum tensor is to assume that the induced metric in the coordinates $(\xi, \overline{\xi}, s, S^-)$ has as non-vanishing components only $g_{\xi\overline{\xi}}$ and g_{s-}

$$g_{ss} = 0 \ , \quad g_{\xi s} = 0 \ , \quad g_{\overline{\xi} s} = 0 \ . \tag{9.2.25}$$

   Obviously the space-time surface must factorize into an orthogonal product of longitudinal and transversal spaces.

4. The condition guaranteeing the product structure of the metric is

$$\begin{aligned} s_{ss} &= m_{+w}\partial_s w(\xi, s)\partial_s S^+(s) + m_{+\overline{w}}\partial_s \overline{w}(\xi, s)\partial_s S^+(s) \ , \\ s_{s\xi} &= m_{+w}\partial_\xi w(\xi)\partial_s S^+(s) \ , \\ s_{s\overline{\xi}} &= m_{+w}\partial_{\overline{\xi}} w(\overline{\xi})\partial_s S^+(s) \ . \end{aligned} \tag{9.2.26}$$

   Thus the function of dynamics is to diagonalize the metric and provide it with strong Kähler property. Obviously the CP_2 projection corresponds to a light-like surface for all values of S^- so that space-time surface is foliated by light-like surfaces and the notion of generalized conformal invariance makes sense for the entire space-time surface rather than only for its boundary or elementary particle horizons.

5. The requirement that the Kähler current is proportional to the instanton current means that only the j^- component of the current is non-vanishing. This gives the following conditions

$$\begin{aligned} & j^\xi \sqrt{g} = \partial_\beta (J^{\xi\beta}\sqrt{g}) = 0 \ , \quad j^{\overline{\xi}}\sqrt{g} = \partial_\beta (J^{\overline{\xi}\beta}\sqrt{g}) = 0 \ , \\ & j^+ \sqrt{g} = \partial_\beta (J^{+\beta}\sqrt{g}) = 0 \ . \end{aligned} \tag{9.2.27}$$

   Since $J^{+\beta}$ vanishes, the condition

$$\sqrt{g} j^+ = \partial_\beta (J^{+\beta}\sqrt{g}) \quad = \quad 0 \tag{9.2.28}$$

   is identically satisfied. Therefore the number of field equations reduces to three.

The physical interpretation of the solution ansatz deserves some comments.

1. The light-like character of the Kähler current brings in mind CP_2 type extremals for which CP_2 projection is light like. This suggests that the topological condensation of CP_2 type extremal occurs on $D_{CP_2} = 3$ helical space-time sheet representing zitterbewegung. In the case of many-body system light-likeness of the current does not require that particles are massless if particles of opposite charges can be present. Field tensor has the form $(J^{\xi\overline{\xi}}, J^{\xi -}, J^{\overline{\xi} -})$. Both helical magnetic field and electric field present as is clear when one replaces the coordinates (S^+, S^-) with time-like and space-like coordinate. Magnetic field dominates but the presence of electric field means that genuine Beltrami field is not in question.

2. Since the induced metric is product metric, 3-surface is metrically product of 2-dimensional surface X^2 and line or circle and obeys product topology. If preferred extremals correspond to asymptotic self-organization patterns, the appearance of the product topology and even metric is not so surprising. Thus the solutions can be classified by the genus of X^2. An interesting question is how closely the explanation of family replication phenomenon in terms of the topology of the boundary component of elementary particle like 3-surface relates to this. The heaviness and instability of particles which correspond to genera $g > 2$ (sphere with more than two handles) might have simple explanation as absence of (stable) $D_{CP_2} = 3$ solutions of field equations with genus $g > 2$.

3. The solution ansatz need not be the most general. Kähler current is light-like and already this is enough to reduce the field equations to the form involving only energy momentum tensor. One might hope of finding also solution ansätze for which Kähler current is time-like or space-like. Space-likeness of the Kähler current might be achieved if the complex coordinates $(\xi, \overline{\xi})$ and hyper-complex coordinates (S^+, S^-) change the role. For this solution ansatz electric field would dominate. Note that the possibility that Kähler current is always light-like cannot be excluded.

4. Suppose that CP_2 projection quite generally defines a foliation of the space-time surface by light-like 3-surfaces, as is suggested by the conformal invariance. If the induced metric has Minkowskian signature, the fourth coordinate x^4 and thus also Kähler current must be time-like or light-like so that magnetic field dominates. Already the requirement that the metric is non-degenerate implies $g_{s4} \neq 0$ so that the metric for the $\xi = constant$ 2-surfaces has a Minkowskian signature. It might well be that there are no solutions with a space-like Kähler current, that the topologization of the Kähler current is equivalent with its light-likeness, and that $D_{CP_2} = 3$ solutions carry dominantly magnetic fields. Thus space-like Kähler current does not allow the lift of the CP_2 projection to be light-like.

Are solutions with time-like or space-like Kähler current possible in $D_{CP_2} = 3$ case?

The following ansatz gives good hopes for obtaining solutions with space-like and time-like Kähler currents.

1. Assign to light-like coordinates coordinates (T, Z) by the formula $T = S^+ + S^-$ and $Z = S^+ - S^-$. Space-time coordinates are taken to be $(\xi, \overline{\xi}, s)$ and coordinate Z. The solution ansatz with time-like Kähler current results when the roles of T and Z are changed. It will however found that same solution ansatz can give rise to both space-like and time-like Kähler current.

2. The solution ansatz giving rise to a space-like Kähler current is defined by the equations

$$T = T(Z, s) \ , \quad w = w(\xi, s) \ . \tag{9.2.29}$$

If T depends strongly on Z, the g_{ZZ} component of the induced metric becomes positive and Kähler current time-like.

3. The components of the induced metric are

$$\begin{array}{ll} g_{ZZ} = m_{ZZ} + m_{TT}\partial_Z T \partial_s T \ , & g_{Zs} = m_{TT}\partial_Z T \partial_s T \ , \\ g_{ss} = s_{ss} + m_{TT}\partial_s T \partial_s T \ , & g_{w\overline{w}} = s_{w\overline{w}} + m_{w\overline{w}}\partial_\xi w \partial_{\overline{\xi}} \overline{w} \ , \\ g_{s\xi} = s_{s\xi} \ , & g_{s\overline{\xi}} = s_{s\overline{\xi}} \ . \end{array} \tag{9.2.30}$$

Topologized Kähler current has only Z-component and 3-dimensional empty space Maxwell's equations guarantee the topologization.

In CP_2 degrees of freedom the contractions of the energy momentum tensor with Christoffel symbols vanish if T^{ss}, $T^{\xi s}$ and $T^{\xi\xi}$ vanish as required by internal consistency. This is guaranteed if the condition

$$J^{\xi s} \ = \ 0 \tag{9.2.31}$$

holds true. Note however that $J^{\xi Z}$ is non-vanishing. Therefore only the components $T^{\xi\overline{\xi}}$ and $T^{Z\xi}$, $T^{Z\overline{\xi}}$ of energy momentum tensor are non-vanishing, and field equations reduce to the conditions

$$\begin{aligned} \partial_{\overline{\xi}}(J^{\xi\overline{\xi}}\sqrt{g}) + \partial_Z(J^{\xi Z}\sqrt{g}) &= 0 \ , \\ \partial_{\xi}(J^{\overline{\xi}\xi}\sqrt{g}) + \partial_Z(J^{\overline{\xi} Z}\sqrt{g}) &= 0 \ . \end{aligned} \tag{9.2.32}$$

In the special case that the induce metric does not depend on z-coordinate equations reduce to holomorphicity conditions. This is achieve if T depends linearly on Z: $T = aZ$.

The contractions with M^4_+ Christoffel symbols come from the non-vanishing of $T^{Z\xi}$ and vanish if the Hamilton Jacobi structure satisfies the conditions

$$\begin{aligned} &\{ {}_{T}^{k}{}_{w} \} = 0 \ , \quad \{ {}_{T}^{k}{}_{\overline{w}} \} = 0 \ , \\ &\{ {}_{Z}^{k}{}_{w} \} = 0 \ , \quad \{ {}_{Z}^{k}{}_{\overline{w}} \} = 0 \end{aligned} \tag{9.2.33}$$

hold true. The conditions are equivalent with the conditions

$$\{ {}_{\pm}^{k}{}_{w} \} = 0 \ , \quad \{ {}_{\pm}^{k}{}_{\overline{w}} \} = 0 \ . \tag{9.2.34}$$

These conditions possess solutions (standard light cone coordinates are the simplest example). Also the second derivatives of $T(s, Z)$ contribute to the second fundamental form but they do not give rise to non-vanishing contractions with the energy momentum tensor. The cautious conclusion is that also solutions with time-like or space-like Kähler current are possible.

$D_{CP_2} = 4$ case

The preceding discussion was for $D_{CP_2} = 3$ and one should generalize the discussion to $D_{CP_2} = 4$ case.

1. Hamilton Jacobi structure for M^4_+ is expected to be crucial also now.

2. One might hope that for $D = 4$ the Kähler structure of CP_2 defines a foliation of CP_2 by 3-dimensional contact structures. This requires that there is a coordinate varying along the field lines of the normal vector field X defined as the dual of the three-form $A \wedge dA = A \wedge J$. By the previous considerations the condition for this reads as $dX = d(log\phi) \wedge X$ and implies $X \wedge dX = 0$. Using the self duality of the Kähler form one can express X as $X^k = J^{kl}A_l$. By a brief calculation one finds that $X \wedge dX \propto X$ holds true so that (somewhat disappointingly) a foliation of CP_2 by contact structures does not exist.

For $D_{CP_2} = 4$ case Kähler current vanishes and this case corresponds to what I have called earlier Maxwellian phase since empty space Maxwell's equations would be indeed satisfied, provided this phase exists at all. It however seems that Maxwell phase is probably realized differently.

1. Solution ansatz with a 3-dimensional M^4_+ projection

The basic idea is that the complex structure of CP_2 is preserved so that one can use complex coordinates (ξ^1, ξ^2) for CP_2 in which CP_2 Christoffel symbols and energy momentum tensor have automatically the desired properties. This is achieved the second light like coordinate, say v, is non-dynamical so that the induced metric does not receive any contribution from the longitudinal degrees of freedom. In this case one has

$$S^+ = S^+(\xi^1, \xi^2) \ , \quad w = w(\xi^1, \xi^2) \ , \quad S^- = constant \ . \tag{9.2.35}$$

The induced metric does possesses only components of type $g_{i\overline{j}}$ if the conditions

$$g_{+w} = 0 \ , \quad g_{+\overline{w}} = 0 \ . \tag{9.2.36}$$

This guarantees that energy momentum tensor has only components of type $T^{i\bar{j}}$ in coordinates (ξ^1, ξ^2) and their contractions with the Christoffel symbols of CP_2 vanish identically. In M^4_+ degrees of freedom one must pose the conditions

$$\{^{\ k}_{w+}\} = 0 \ , \quad \{^{\ k}_{\overline{w}+}\} = 0 \ , \quad \{^{\ k}_{++}\} = 0 \ . \tag{9.2.37}$$

on Christoffel symbols. These conditions are satisfied if the M^4_+ metric does not depend on S^+:

$$\partial_+ m_{kl} \ = \ 0 \ . \tag{9.2.38}$$

This means that m_{-w} and $m_{-\overline{w}}$ can be non-vanishing but like m_{+-} they cannot depend on S^+.

The second derivatives of S^+ appearing in the second fundamental form are also a source of trouble unless they vanish. Hence S^+ must be a linear function of the coordinates ξ^k:

$$S^+ \ = \ a_k\xi^k + \overline{a}_k\overline{\xi}^k \ . \tag{9.2.39}$$

Field equations are the counterparts of empty space Maxwell equations $j^\alpha = 0$ but with M^4_+ coordinates (u, w) appearing as dynamical variables and entering only through the induced metric. By holomorphy the field equations can be written as

$$\partial_j(J^{j\bar{i}}\sqrt{g}) = 0 \ , \quad \partial_{\bar{j}}(J^{\bar{j}i}\sqrt{g}) = 0 \ , \tag{9.2.40}$$

and can be interpreted as conditions stating the holomorphy of the contravariant Kähler form.

What is remarkable is that the M^4_+ projection of the solution is 3-dimensional light like surface and that the induced metric has Euclidian signature. Light front would become a concrete geometric object with one compactified dimension rather than being a mere conceptualization. One could see this as topological quantization for the notion of light front or of electromagnetic shock wave, or perhaps even as the realization of the particle aspect of gauge fields at classical level.

If the latter interpretation is correct, quantum classical correspondence would be realized very concretely. Wave and particle aspects would both be present. One could understand the interactions of charged particles with electromagnetic fields both in terms of absorption and emission of topological field quanta and in terms of the interaction with a classical field as particle topologically condenses at the photonic light front.

For CP_2 type extremals for which M^4_+ projection is a light like curve correspond to a special case of this solution ansatz: transversal M^4_+ coordinates are constant and S^+ is now arbitrary function of CP_2 coordinates. This is possible since M^4_+ projection is 1-dimensional.

2. Are solutions with a 4-dimensional M^4_+ projection possible?

The most natural solution ansatz is the one for which CP_2 complex structure is preserved so that energy momentum tensor has desired properties. For four-dimensional M^4_+ projection this ansatz does not seem to make promising since the contribution of the longitudinal degrees of freedom implies that the induced metric is not anymore of desired form since the components $g_{ij} = m_{+-}(\partial_{\xi^i}S^+\partial_{\xi^j}S^- + m_{+-}\partial_{\xi^i}S^-\partial_{\xi^j}S^+)$ are non-vanishing.

1. The natural dynamical variables are still Minkowski coordinates $(w, \overline{w}, S^+, S^-)$ for some Hamilton Jacobi structure. Since the complex structure of CP_2 must be given up, CP_2 coordinates can be written as (ξ, s, r) to stress the fact that only "one half" of the Kähler structure of CP_2 is respected by the solution ansatz.

2. The solution ansatz has the same general form as in $D = 3$ case and must be symmetric with respect to the exchange of M^4_+ and CP_2 coordinates. Transverse coordinates are mapped to transverse ones and longitudinal coordinates to longitudinal ones:

$$(S^+, S^-) = (S^+(s, r), S^-(s, r)) \ , \quad w = w(\xi) \ . \tag{9.2.41}$$

This ansatz would describe ordinary Maxwell field in M^4_+ since the roles of M^4_+ coordinates and CP_2 coordinates are interchangeable.

It is however far from obvious whether there are any solutions with a 4-dimensional M^4_+ projection. That empty space Maxwell's equations would allow only the topologically quantized light fronts as its solutions would realize quantum classical correspondence very concretely.

The recent view conforms with this intuition. The Maxwell phase is certainly physical notion but would correspond effective fields experience by particle in many-sheeted space-time. Test particle topological condenses to all the space-time sheets with projection to a given region of Minkowski space and experiences essentially the sum of the effects caused by the induced gauge fields at different sheets. This applies also to gravitational fields interpreted as deviations from Minkowski metric.

The transition to GRT and QFT picture means the replacement of many-sheeted space-time with piece of Minkowski space with effective metric defined as the sum of Minkowski metric and deviations of the induced metrics of space-time sheets from Minkowski metric. Effective gauge potentials are sums of the induced gauge potentials. Hence the rather simple topologically quantized induced gauge fields associated with space-time sheets become the classical fields in the sense of Maxwell's theory and gauge theories.

$D_{CP_2} = 2$ case

Hamilton Jacobi structure for M^4_+ is assumed also for $D_{CP_2} = 2$, whereas the contact structure for CP_2 is in $D = 2$ case replaced by the induced Kähler structure. Topologization yields vanishing Kähler current. Light-likeness provides a second manner to achieve vanishing Lorentz force but one cannot exclude the possibility of time- and space-like Kähler current.

1. Solutions with vanishing Kähler current

1. String like objects, which are products $X^2 \times Y^2 \subset M^4_+ \times CP_2$ of minimal surfaces Y^2 of M^4_+ with geodesic spheres S^2 of CP_2 and carry vanishing gauge current. String like objects allow considerable generalization from simple Cartesian products of $X^2 \times Y^2 \subset M^4 \times S^2$. Let $(w, \overline{w}, S^+, S^-)$ define the Hamilton Jacobi structure for M^4_+. $w = constant$ surfaces define minimal surfaces X^2 of M^4_+. Let ξ denote complex coordinate for a sub-manifold of CP_2 such that the embedding to CP_2 is holomorphic: $(\xi^1, \xi^2) = (f^1(\xi), f^2(\xi))$. The resulting surface $Y^2 \subset CP_2$ is a minimal surface and field equations reduce to the requirement that the Kähler current vanishes: $\partial_{\overline{\xi}}(J^{\xi\overline{\xi}}\sqrt{g_2}) = 0$. One-dimensional strings are deformed to 3-dimensional cylinders representing magnetic flux tubes. The oscillations of string correspond to waves moving along string with light velocity, and for more general solutions they become TGD counterparts of Alfven waves associated with magnetic flux tubes regarded as oscillations of magnetic flux lines behaving effectively like strings. It must be emphasized that Alfven waves are a phenomenological notion not really justified by the properties of Maxwell's equations.

2. Also electret type solutions with the role of the magnetic field taken by the electric field are possible. $(\xi, \overline{\xi}, u, v)$ would provide the natural coordinates and the solution ansatz would be of the form

$$(s, r) = (s(u, v), r(u, v)) \quad , \quad \xi = constant \quad , \tag{9.2.42}$$

and corresponds to a vanishing Kähler current.

3. Both magnetic and electric fields are necessarily present only for the solutions carrying non-vanishing electric charge density (proportional to $\overline{B} \cdot \overline{A}$). Thus one can ask whether more general solutions carrying both magnetic and electric field are possible. As a matter fact, one must first answer the question what one really means with the magnetic field. By choosing the coordinates of 2-dimensional CP_2 projection as space-time coordinates one can define what one means with magnetic and electric field in a coordinate invariant manner. Since the CP_2 Kähler form for the CP_2 projection with $D_{CP_2} = 2$ can be regarded as a pure Kähler magnetic field, the induced Kähler field is either magnetic field or electric field.

The form of the ansatz would be

$$(s,r) = (s,r)\,(u,v,w,\overline{w}) \ , \quad \xi = constant \ . \tag{9.2.43}$$

As a matter fact, CP_2 coordinates depend on two properly chosen M^4 coordinates only.

1. Solutions with light-like Kähler current

There are large classes of solutions of field equations with a light-like Kähler current and 2-dimensional CP_2 projection.

1. Massless extremals for which CP_2 coordinates are arbitrary functions of one transversal coordinate $e = f(w,\overline{w})$ defining local polarization direction and light like coordinate u of M^4_+ and carrying in the general case a light like current. In this case the holomorphy does not play any role.

2. The string like solutions thickened to magnetic flux tubes carrying TGD counterparts of Alfven waves generalize to solutions allowing also light-like Kähler current. Also now Kähler metric is allowed to develop a component between longitudinal and transversal degrees of freedom so that Kähler current develops a light-like component. The ansatz is of the form

$$\xi^i = f^i(\xi) \ , \ w = w(\xi) \ , \ S^- = s^- \ , \ S^+ = s^+ + f(\xi,\overline{\xi}) \ .$$

   Only the components $g_{+\xi}$ and $g_{+\overline{\xi}}$ of the induced metric receive contributions from the modification of the solution ansatz. The contravariant metric receives contributions to $g^{-\xi}$ and $g^{-\overline{\xi}}$ whereas $g^{+\xi}$ and $g^{+\overline{\xi}}$ remain zero. Since the partial derivatives $\partial_\xi\partial_+h^k$ and $\partial_{\overline{\xi}}\partial_+h^k$ and corresponding projections of Christoffel symbols vanish, field equations are satisfied. Kähler current develops a non-vanishing component j^-. Apart from the presence of the electric field, these solutions are highly analogous to Beltrami fields.

3. Do scalar wave pulses represent a solution type with non-vanishing but not light-like Kähler current?

Since longitudinal polarizations are possible only for off mass shell virtual photons, physical intuition suggests that scalar wave pulse solutions describing the propagation of longitudinal electric field with light velocity cannot appear as asymptotic field patterns. This is also consistent with the claim that scalar wave pulses are associated with the transients involved with sudden switching of electric voltage on or off. Let $M^4 = M^2 \oplus E^2$ be the standard decomposition of M^4 to flat longitudinal and transversal spaces, and S^2 a homologically non-trivial geodesic sphere of CP_2. The simplest solution ansatz corresponds to a surface $X^2 \times Y^2$, $X^2 \subset E^2$, such that Y^2 is a surface defined by a map $S^2 \to M^2$ (or vice versa).

Energy momentum tensor is in both longitudinal and transversal degrees of freedom proportional to the corresponding part of the induced metric. Field equations are trivially true in the transversal degrees of freedom. The calculation of the divergence of energy momentum tensor demonstrates that Kähler current can be regarded as a vector field

$$j^\alpha = \frac{1}{4} J^{\alpha\beta}\partial_\beta L$$

defined by the Kähler action density acting as Hamiltonian. Poisson bracket is defined by the pseudo-symplectic form associated with the induced Kähler form with respect to the induced metric rather that of S^2 (using S^2-coordinates as coordinates for Y^2, the square of this pseudo-symplectic form is equal to metric multiplied by the ratio $det(g(Y^2))/det(g(S^2))$).

In longitudinal degrees of freedom field equations are minimal surface equations with a source term proportional to the Kähler current divided by the Kähler action density. The vanishing of the Kähler current is possible only if Kähler action density is constant. This condition is true in the approximation that the induced metric for Y^2 is flat, that is at the limit when M^4 projection has size larger than size of CP_2 projection and that induced metric has Minkowskian signature). It is not clear whether the minimal surface property of Y^2 in $M^2 \times S^2$ is consistent with the constancy of the Kähler action density. This would suggest that classical gravitational interactions eliminate scalar wave pulses as asymptotic field patterns and cause the deviation from the minimal surface property and the non-vanishing of the Kähler current. The fact that solution becomes "instanton" like Euclidian solution when S^+ and S^- become constant suggests that the M^4 projection of the solution quite generally has a finite extension in time direction.

Could $D_{CP_2} = 2 \rightarrow 3$ transition occur in rotating magnetic systems?

I have studied the embeddings of simple cylindrical and helical magnetic fields in various applications of TGD to condensed matter systems, in particular in attempts to understand the strange findings about rotating magnetic systems [K110].

Let S^2 be the homologically non-trivial geodesic sphere of CP_2 with standard spherical coordinates $(U \equiv cos(\theta), \Phi)$ and let (t, ρ, ϕ, z) denote cylindrical coordinates for a cylindrical space-time sheet. The simplest possible space-time surfaces $X^4 \subset M^4_+ \times S^2$ carrying helical Kähler magnetic field depending on the radial cylindrical coordinate ρ, are given by:

$$\begin{array}{ll} U = U(\rho) \ , & \Phi = n\phi + kz \ , \\ J_{\rho\phi} = n\partial_\rho U \ , & J_{\rho z} = k\partial_\rho U \ . \end{array} \tag{9.2.44}$$

This helical field is not Beltrami field as one can easily find. A more general ansatz corresponding defined by

$$\Phi = \omega t + kz + n\phi$$

would in cylindrical coordinates give rise to both helical magnetic field and radial electric field depending on ρ only. This field can be obtained by simply replacing the vector potential with its rotated version and provides the natural first approximation for the fields associated with rotating magnetic systems.

A non-vanishing vacuum charge density is however generated when a constant magnetic field is put into rotation and is implied by the condition $\overline{E} = \overline{v} \times \overline{B}$ stating vanishing of the Lorentz force. This condition does not follow from the induction law of Faraday although Faraday observed this effect first. This is also clear from the fact that the sign of the charge density depends on the direction of rotation.

The non-vanishing charge density is not consistent with the vanishing of the Kähler 4-current and requires a 3-dimensional CP_2 projection and topologization of the Kähler current. Beltrami condition cannot hold true exactly for the rotating system. The conclusion is that rotation induces a phase transition $D_{CP_2} = 2 \rightarrow 3$. This could help to understand various strange effects related to the rotating magnetic systems [K110]. For instance, the increase of the dimension of CP_2 projection could generate join along boundaries bonds/flux tubes and wormhole contacts (see **Fig. ??** in the appendix of this book) leading to the transfer of charge between different space-time sheets. The possibly resulting flow of gravitational flux to larger space-time sheets might help to explain the claimed antigravity effects.

9.2.4 Is Preferred ExtremalProperty Equivalent With The Topologization/Light-Likeness Of Kähler Current And With Second Law?

The basic question is whether the Kähler current is either topologized or light-like for all extremals or only for the preferred extremals of Kähler action in some sense, presumably asymptotically as suggested by the fact that generalized Beltrami fields correspond to asymptotic self-organization patterns, when dissipation has become insignificant.

1. The generalized Beltrami conditions or light-likeness can hold true only asymptotically. First of all, generic non-asymptotic field configurations have $D_{CP_2} = 4$, and would thus carry a vanishing Kähler four-current if Beltrami conditions were satisfied universally rather than only asymptotically. $j^\alpha = 0$ would obviously hold true also for the asymptotic configurations, in particular those with $D_{CP_2} < 4$ so that empty space Maxwell's field equations would be universally satisfied for asymptotic field configurations with $D_{CP_2} < 4$.

2. The failure of the generalized Beltrami conditions would mean that Kähler field is completely analogous to a dissipative Maxwell field since $\overline{j} \cdot \overline{E}$ is non-vanishing (note that isometry currents are conserved although energy momentum tensor is not). Quantum classical correspondence states that classical space-time dynamics is by its classical non-determinism able to mimic the non-deterministic sequence of quantum jumps at space-time level, in particular dissipation in various length scales defined by the hierarchy of space-time sheets. Classical fields could represent "symbolically" the average dynamics, in particular dissipation, in shorter length scales. For instance, vacuum 4-current would be a symbolic representation for the average of the currents consisting of elementary particles.

Is preferred extremal property equivalent with generalized Beltrami conditions?

Previous findings inspire the hypothesis that generalized Beltrami conditions express algebraically the absolute minimization conditions so that they make sense also in the p-adic case.

1. Generalized Beltrami conditions are satisfied by the asymptotic field configurations representing self-organization patterns. For non-asymptotic fields vacuum Lorentz force is non-vanishing and does work in Maxwellian sense so that $\overline{j} \cdot \overline{E}$ is non-vanishing. This would mean that the dynamics defined by Kähler action could in principle predict even the values of the parameters related to dissipation such as conductivities and viscosities. The space-time sheets of the many-sheeted space-time would be busily modelling its own physics in shorter length scales.

2. Preferred extremal property implies that single space-time surface goes through given 3-surface apart from the non-uniqueness caused by the non-determinism of Kähler action. This gives *four* additional local conditions to the initial values of field equations fixing the time derivatives of the four dynamical embedding space coordinates (conditions are analogous to Bohr conditions).

   The topologization of the Kähler current current gives also *four* local conditions:
   i) For $D_{CP_2} < 4$ the vanishing of instanton density gives one condition, and the proportionality of the Kähler current to instanton current gives 3 conditions since the proportionality factor is an arbitrary function of CP_2 coordinates. Altogether this makes four conditions.
   ii) For $D_{CP_2=4}$ the vanishing of the Kähler current gives four conditions.
   This encourages to think that the preferred extremal property forces the asymptotic behavior (final values instead of initial values) to correspond to dissipation-less state characterized by the generalized Beltrami conditions.

Is preferred extremal property equivalent with the second law?

The fact that Beltrami conditions are associated with the asymptotic dynamics suggests that preferred extremal property is equivalent with the second law at space-time level. Or putting it more cautiously: second law at space-time level could be equivalent with preferred extremal property.

For space-time sheets with negative time orientation and negative energy, say "massless extremals" representing phase conjugate laser waves, field configurations would approach non-dissipating ones in the geometric past, and the arrow of geometric time would be opposite to the standard one in this case. This situation is possible for space-time sheets of finite duration, in particular virtual particle like space-time sheets or the negative energy space-time sheets extending down to the boundary of embedding space (moment of "big bang"). This would explain at the space-time level the change of arrow of time and breaking of the second law observed for the phase conjugate laser waves (used to generate healing and error correction for instance). In TGD framework second law is not a producer of a thermal chaos but Darwinian selector since state function reduction and state preparation by self measurements lead from a state with positive entanglement entropy to that with a negative entanglement entropy (defined number theoretically), and possessing only finitely extended rational entanglement identifiable as a bound state entanglement.

According to the recent view preferred extremal property corresponds to space-time correlate for quantum criticality and indeed induces long range correlations. The resulting non-local long range correlations could serve as correlates for bound state entanglement. More concretely, the stable join along boundaries bonds/flux tubes would be the correlates for bound state entanglement whereas topological light rays analogous to the exchange of virtual photons could serve as classical correlates for unbound entanglement. The closedness (periodicity) of the field lines of Beltrami fields for space-like Kähler current and periodicity of the field pattern for the time like Kähler current could be space-time correlates for the rational entanglement. The pinary expansions of rational numbers which are periodic after finite number of pinary digits indeed represent closed orbits in the set of integers modulo p. Amusingly, the first non-periodic pits of the expansion would in fact be analogous to the dissipative period.

Macro-temporal quantum coherence integrates sequences of quantum jumps to single effective quantum jump so that effectively a fractal hierarchy of quantum jumps emerges having the fractal hierarchy of time scales of dissipation resulting from many-sheetedness as a correlate. Even the anatomy of quantum jump could have space-time correlate. The final state of the quantum jump would correspond to highly negentropic and non-dissipating topologically quantized generalized Beltrami fields. State function reduction and preparation would correspond to the non-deterministic dissipative approach to the non-dissipative Beltrami field configuration. The points of space-time sheets with vanishing Kähler 4-currents would be unstable against quantum jumps generating an instability of the Beltrami field leading to a field configuration with a non-vanishing Lorentz 4-force and emission of topological light rays representing unstable entanglement. Quantum jump would have this kind of instability as a natural space-time correlate.

To sum up, the main lessons would be following.

1. The ability of basically non-dissipative dynamics to mimic dissipative dynamics in terms of energy momentum tensor would be the basic reason for why space-times must be 4-surfaces.

2. If prefered extremal property is correct principle, it must provide a space-time correlate for the second law, which is the Darwinian selector of the most information rich patterns rather than a thermal killer.

9.2.5 Generalized Beltrami Fields And Biological Systems

The following arguments support the view that generalized Beltrami fields play a key role in living systems, and that $D_{CP_2} = 2$ corresponds to ordered phase, $D_{CP_2} = 3$ to spin glass phase and $D_{CP_2} = 4$ to chaos, with $D_{CP_2} = 3$ defining life as a phenomenon at the boundary between order and chaos.

Why generalized Beltrami fields are important for living systems?

Chirality, complexity, and high level of organization make $D_{CP_2} = 3$ generalized Beltrami fields excellent candidates for the magnetic bodies of living systems.

1. Chiral selection is one of the basic signatures of living systems. Beltrami field is characterized by a chirality defined by the relative sign of the current and magnetic field, which means parity breaking. Chirality reduces to the sign of the function ψ appearing in the topologization condition and makes sense also for the generalized Beltrami fields.

2. Although Beltrami fields can be extremely complex, they are also extremely organized. The reason is that the function α is constant along flux lines so that flux lines must in the case of compact Riemann 3-manifold belong to 2-dimensional $\alpha = constant$ closed surfaces, in fact two-dimensional invariant tori [B18].

For generalized Beltrami fields the function ψ is constant along the flow lines of the Kähler current. Space-time sheets with 3-dimensional CP_2 projection serve as an illustrative example. One can use the coordinates for the CP_2 projection as space-time coordinates so that one space-time coordinate disappears totally from consideration. Hence the situation reduces to a flow in a 3-dimensional sub-manifold of CP_2. One can distinguish between three types of flow lines corresponding to space-like, light-like and time-like topological current. The 2-dimensional $\psi = constant$ invariant manifolds are sub-manifolds of CP_2. Ordinary Beltrami fields are a special case of space-like flow with flow lines belonging to the 2-dimensional invariant tori of CP_2. Time-like and light-like situations are more complex since the flow lines need not be closed so that the 2-dimensional $\psi = constant$ surfaces can have boundaries.

For periodic self-organization patterns flow lines are closed and $\psi = constant$ surfaces of CP_2 must be invariant tori. The dynamics of the periodic flow is obtained from that of a steady flow by replacing one spatial coordinate with effectively periodic time coordinate. Therefore topological notions like helix structure, linking, and knotting have a dynamical meaning at the level of CP_2 projection. The periodic generalized Beltrami fields are highly organized also in the temporal domain despite the potentiality for extreme topological complexity.

For these reasons topologically quantized generalized Beltrami fields provide an excellent candidate for a generic model for the dynamics of biological self-organization patterns. A natural guess is that many-sheeted magnetic and Z^0 magnetic fields and their generalizations serve as templates for the helical molecules populating living matter, and explain both chiral selection, the complex linking and knotting of DNA and protein molecules, and even the extremely complex and self-organized dynamics of biological systems at the molecular level.

The intricate topological structures of DNA, RNA, and protein molecules are known to have a deep significance besides their chemical structure, and they could even define something analogous to the genetic code. Usually the topology and geometry of bio-molecules is believed to reduce to chemistry. TGD suggests that space-like generalized Beltrami fields serve as templates for the formation of bio-molecules and bio-structures in general. The dynamics of bio-systems would in turn utilize the time-like Beltrami fields as templates. There could even exist a mapping from the topology of magnetic flux tube structures serving as templates for bio-molecules to the templates of self-organized dynamics. The helical structures, knotting, and linking of bio-molecules would thus define a symbolic representation, and even coding for the dynamics of the bio-system analogous to written language.

$D_{CP_2} = 3$ systems as boundary between $D_{CP_2} = 2$ order and $D_{CP_2} = 4$ chaos

The dimension of CP_2 projection is basic classifier for the asymptotic self-organization patterns.

1. $D_{CP_2} = 4$ phase, dead matter, and chaos

$D_{CP_2} = 4$ corresponds to the ordinary Maxwellian phase in which Kähler current and charge density vanish and there is no topologization of Kähler current. By its maximal dimension this phase would naturally correspond to disordered phase, ordinary dead matter. If one assumes that Kähler charge corresponds to either em charge or Z^0 charge then the signature of this state of matter would be em neutrality or Z^0 neutrality.

2. $D_{CP_2} = 2$ phase as ordered phase

By the low dimension of CP_2 projection $D_{CP_2} = 2$ phase is the least stable phase possible only at cold space-time sheets. Kähler current is either vanishing or light-like, and Beltrami fields are not possible. This phase is highly ordered and much like a topological quantized version of ferro-magnet. In particular, it is possible to have a global coordinate varying along the field lines of the vector potential also now. The magnetic and Z^0 magnetic body of any system is a candidate for this kind of system.

3. $D_{CP_2} = 3$ corresponds to living matter

$D_{CP_2} = 3$ corresponds to highly organized phase characterized in the case of space-like Kähler current by complex helical structures necessarily accompanied by topologized Kähler charge density $\propto \overline{A}\cdot\overline{B} \neq 0$ and Kähler current $\overline{E}\times\overline{A}+\phi\overline{B}$. For time like Kähler currents the helical structures are replaced by periodic oscillation patterns for the state of the system. By the non-maximal dimension of CP_2 projection this phase must be unstable against too strong external perturbations and cannot survive at too high temperatures. Living matter is thus excellent candidate for this phase and it might be that the interaction of the magnetic body with living matter makes possible the transition from $D_{CP_2} = 2$ phase to the self-organizing $D_{CP_2} = 3$ phase.

Living matter which is indeed populated by helical structures providing examples of space-like Kähler current. Strongly charged lipid layers of cell membrane might provide example of time-like Kähler current. Cell membrane, micro-tubuli, DNA, and proteins are known to be electrically charged and Z^0 charge plays key role in TGD based model of catalysis discussed in [?]. For instance, denaturing of DNA destroying its helical structure could be interpreted as a transition leading from $D = 3$ phase to $D = 4$ phase. The prediction is that the denatured phase should be electromagnetically (and/or Z^0) neutral.

Beltrami fields result when Kähler charge density vanishes. For these configurations magnetic field and current density take the role of the vector potential and magnetic field as far as the contact structure is considered. For Beltrami fields there exist a global coordinate along the field lines of the vector potential but not along those of the magnetic field. As a consequence, the covariant consistency condition $(\partial_s - qeA_s)\Psi = 0$ frequently appearing in the physics of super conducting systems would make sense along the flow lines of the vector potential for the order parameter of Bose-Einstein condensate. If Beltrami phase is super-conducting, then the state of the system must change in the transition to a more general phase. Since the field lines of the vector potential define chaotic orbits in this phase, the loss of coherence of the order parameter implying the loss of superconductivity by random collisions of particles is what one expects to happen.

The existence of these three phases brings in mind systems allowing chaotic de-magnetized phase above critical temperature T_c, spin glass phase at the critical point, and ferromagnetic phase below T_c. Similar analogy is provided by liquid phase, liquid crystal phase possible in the vicinity of the critical point for liquid to solid transition, and solid phase. Perhaps one could regard $D_{CP_2} = 3$ phase and life as a boundary region between $D_{CP_2} = 2$ order and $D_{CP_2} = 4$ chaos. This would naturally explain why life as it is known is possible in relatively narrow temperature interval.

9.3 The Scalar Waves Of Tesla, Bio-Systems AsElectrets, And Electric-Magnetic Duality

The scalar waves or so called non-Hertzian waves of Nikola Tesla belong to the fringe region of science. Many proponents of free energy believe that scalar waves might provide a basis for a new energy and communication technologies. Tesla himself was isolated from the official science and found no place in text books because his hypothesis about scalar waves did not fit within the framework of the Maxwell's electrodynamics. Personally I justified my personal prejudices against scalar waves by the observation that the formulations for the notion of scalar waves that I had seen seemed to be in a conflict with the cherished gauge invariance of gauge theories. The discussions with a Finnish free energy enthusiast Juha Hartikka however led me to reconsider the status of the scalar waves.

The surprise was that the non-Hertzian waves of Tesla might be possible in TGD framework. One can imagine two alternative ways to obtain them.

1. TGD allows so called massless extremals (MEs, topological light rays) as non-linear generalization of Maxwellian plane waves. They are characterized by light-like wave vector and polarization vector orthogonal to it and these vectors can also depend on space-time position [K16]. The most general wave is a pulse with arbitrary profile moving along ME with light-velocity along them and preserving its shape.

   Since TGD space-time is many-sheeted one can take two waves of this kind on top of each other in the sense that their M^4 projections intersect in some region of M^4. The effective space-time is defined by a piece of Minkowski space with effective metric which is sum of M^4 metric and deviations of the metrics of sheets from M^4 metric. Effective gauge potentials are sums of the induced gauge potentials. For two MEs the potentials at the two sheets and if the wave vectors can be chosen to be in opposite direction in which case one obtains an effective standing wave with non-vanishing net energy but vanishing 3-momentum and classical spin. Since MEs can carry light-like charge current the resulting system carries non-vanishing charge density and vanishing current Fourier transforms of the pair give rise to massive spinless states having identification as scalar waves possibly carrying em charge.

   In TGD framework classical gauge boson fields of standard model correspond two-sheeted structures - perhaps pairs of MEs connected by wormhole contact pairs having interpretation as gauge boson. One can consider the possibility that the classical space-time correlate for gauge bosons massivation at the level of MEs is this kind of pair of spacetime sheets. For massive gauge bosons the wave vector directions of the two sheets would be opposite in the rest system and spin would be vanishing.

2. The original proposal could have been inspired by the electric-magnetic duality of TGD suggesting a large number of solutions of field equations representing constant energy density configurations of electric field assignable to bio-electrets, which would be in a well-defined sense dual to the magnetic flux tube structures with analogous properties. Also classical gravitational fields generated by classical field energy could be important in the living matter. One must however take this proposal with a big grain of salt since there is no proof for the actual existence of this kind of solutions. Furthermore, one can obtain TGD counterparts of scalar waves as pairs of MEs.

In the following only the candidate for scalar waves obtained as single-sheeted space-time is considered.

9.3.1 The Properties Of The Scalar Waves

Perhaps the most important properties of the scalar waves are following.

1. Scalar waves involve some kind of oscillatory process in the direction of the propagation of the wave. The analogy with sound waves suggests that the oscillation could relate to charge density, or more generally to 4-current in the direction of the wave. Even massless extremals (MEs), which are essentially topological light rays, involve vacuum current and vacuum charge density which oscillates in the direction of propagation.

2. Scalar waves are believed to carry electric field in the direction of the wave motion so that the identification of MEs as scalar waves is not possible. The presence of only electric field means that scalar wave is characterized solely by the scalar potential. This kind of solution is excluded by the gauge invariance and linearity of Maxwell's electrodynamics in vacuum.

9.3.2 Could Nonlinearity Of TGD Allow Scalar Waves?

One is led to ask whether the nonlinearity of TGD might allow existence for scalar waves.

1. In TGD based electrodynamics CP_2 coordinates are the primary dynamical degrees of freedom gauge fields being secondary dynamical variables induced from the spinor curvature of CP_2. Field equations are extremely nonlinear allowing among other things vacuum 4-currents (even Faraday's unipolar generator involves vacuum charge density changing its sign when the direction of rotation of magnet changes its sign). This gives hopes about finding solutions of field equations with the properties assigned to the hypothetical scalar waves.

2. Interestingly, in TGD framework the canonical symmetries of CP_2 are dynamical symmetries and act as isometries of WCW of 3-surfaces. Canonical transformations act formally as $U(1)$ gauge transformations but, rather than being gauge symmetries, they are dynamical generating new physical configurations and are partially responsible for the quantum spin glass degeneracy of the TGD universe. As a matter fact, also diffeomorphisms of M^4 act as dynamical symmetries in the lowest order.

3. Magnetic flux tubes represent fundamental solutions of field equations and the simplest magnetic flux tubes can be characterized as maps from a region of a 2-dimensional Euclidian hyperplane E^2 of Minkowski space to a geodesic sphere S^2 of CP_2.

4. Electric-magnetic duality is a fundamental symmetry of the WCW geometry. Therefore there should exist solutions dual to the magnetic flux tubes carrying only electric fields and perhaps allowing interpretation as waves. These solutions would be characterized by a map from a region of the Minkowskian hyperplane M^2 of Minkowski space to S^2. This kind solution ansatz makes sense since it formally provides the solutions of a field theory from M^2 to S^2.

9.3.3 Lowest Order Solution Ansatz

One can write the field equations exlicitely. They are however extremely nonlinear and without physical intuition one cannot say much about the solution spectrum of these equations. One can however make simplifying assumptions to get grasp to the problem.

1. The effect of classical gravitation can be assumed to be extremely weak except possibly at some singular regions associated with the solutions.

2. In Maxwellian theory without sources gauge current vanishes identically. This would suggest that it is good to start from a zeroth order solution ansatz with this property so that the non-vanishing of the vacuum current would be solely due to gravitational effects. It deserves to be noticed that Tesla proposed also that non-Hertzian radiation fields involve a kind of radiation charge.

   In principle, one can imbed a portion of any solution of Maxwell's equations in empty space as a space-time sheet (note the occurrence of the topological quantization) using M^4 coordinates as preferred coordinates. Field equations are satisfied in the lowest order in R^2. The canonical symmetries of CP_2 act as dynamical symmetries for these solution ansätze and one obtains infinite degeneracy of the space-time surfaces representing the same Kähler field.

3. Constant electric field represents the simplest field configuration one can imagine. Therefore it is reasonable to start with this kind of solution ansatz and to look whether gravitational corrections affect the solution and bring in the wave aspect.

4. Since wave motion is hoped to result, it is useful to choose the space-time coordinates in an appropriate manner. Light like coordinates (x^+, x^-, x, y) of M^4 are thus very natural. They are defined by the conditions

$$t = (x^+ + x^-)/2 \ , \quad z = (x^+ - x^-)/2 \ ,$$

   with (t, x, y, z) referring to the linear Minkowski coordinates such that t is time coordinate. In these coordinates the line element of M^2 has the form $ds^2 = -2dx^+dx^-$ so that one has $g_{+-} = -1$.

5. Using the spherical coordinates $(u = cos(\Theta), \Phi)$ for the geodesic sphere S^2 of CP_2, the zeroth order solution ansatz has the following form:

$$u \equiv u_0 = \omega_1 x^+ \ , \quad \Phi \equiv \Phi_0 = \omega_2 x^- \ . \tag{9.3.1}$$

   Since electromagnetic, Z^0 and color fields are proportional to Kähler form for the solution type considered, one can restrict the consideration to the induced Kähler form. Denoting the Kähler form of CP_2 by J_{kl}, by noticing that S^2 Kähler form is given by $J_{u\Phi} = 1$ (forgetting the precise normalization factor), and using the expressions $\left[s_{uu} = R^2/(1-u^2), s_{\Phi\Phi} = R^2(1-u^2)\right]$ for the metric of S^2, one can write the induced line element and the non-vanishing component of the induced Kähler form as

$$\begin{aligned} ds^2 &= -2dx^+dx^- + \frac{R^2\omega_1^2}{1-u^2}(dx^+)^2 + R^2\omega_2^2(1-u^2)(dx^-)^2 - dx^2 - dy^2 \ , \\ J_{+-} &= \partial_+ u \partial_- \Phi = \omega_1\omega_2 \ , \\ J^{+-} &= \frac{\omega_1\omega_2}{det(g)} \ . \end{aligned} \tag{9.3.2}$$

   Since the determinant of the induced metric is constant, J^{+-} describes constant electric field and that Kähler current j^α is vanishes. This means that Maxwell's equations hold true in the zeroth order approximation as required.

Apart from the normalization factors the energy momentum tensor in the longitudinal degrees of freedom is given by

$$T^{\alpha\beta}(long) = g^{\alpha\beta}L/4 \ ,$$

In the transversal degrees of freedom similar expression but with opposite sign holds true. Here L is Kähler action which is essentially electric energy density and constant.

In M^4 degrees of freedom the field equations express conservation of the energy momentum currents and are satisfied to order R^2 since the action is constant. These equations imply that action density is constant. This forces to ask whether all perturbatively constructible solutions represent a constant Kähler electric field locally.

In CP_2 degrees of freedom field equations involve a sum of two terms: the first term involves the contraction of the energy momentum tensor with the second fundamental form whereas the second term involves Kähler current. Since Kähler current vanishes, the latter term vanishes and one can say that field equations are satisfied in zeroth order approximation (the term involving energy momentum tensor is proportional to CP_2 length squared and thus small). For exactly vanishing vacuum current the field equations would reduce to the equations for a minimal surface:

$$g^{\alpha\beta}D_\beta\partial_\alpha h^k = 0 \ , \tag{9.3.3}$$

where the embedding space coordinates h^k corresponds to u and Φ now. The same equations result also in M^4 degrees of freedom by requiring that the terms of order R^2 in the equation for the energy momentum conservation vanish.

This equation is not satisfied exactly as is easy to see. The non-vanishing components of the trace of the second fundamental form are given by

$$\begin{aligned} g^{\alpha\beta}D_\beta\partial_\alpha u &= -\left\{{}^{\ u}_{\Phi\ \Phi}\right\}\omega_2^2 \times \left[1 - g^{++}\omega_1^2R^2/(1-u^2)\right] \ , \\ g^{\alpha\beta}D_\beta\partial_\alpha \Phi &= -\left\{{}^{\ \Phi}_{u\ \Phi}\right\}\omega_1\omega_2 \times \left[1 - g^{--}\omega_2^2R^2(1-u^2)\right] \ . \end{aligned} \tag{9.3.4}$$

Here $\left\{{}^{\ \alpha}_{\beta\ \gamma}\right\}$ denote the components of the Riemann connection for sphere. It is seen that the connection term gives contributions which vanish only at $u = 0$ which corresponds to the equator of the geodesic sphere S^2. At poles the minimal surface condition fails to be satisfied.

9.3.4 First Order Corrections To The Solution Ansatz

To take into account gravitational corrections one must modify the solution ansatz in such a way that x^- does not appear in the field equations at all: this guarantees that field equations reduce to ordinary differential equations. The modification is following:

$$u = u_0 + u_1(x^+) \ , \quad \Phi = \Phi_0 + \Phi_1(x^+) \ . \tag{9.3.5}$$

The modification affects the electric field and vacuum current and allows the compensation of the terms resulting form the contractions of the energy momentum tensor and vacuum current. The modification means that wave equations are still satisfied for u and Φ. Note that second fundamental form does not contain second derivative terms in the lowest order approximation.

The derivation of the differential equations for u_1 and Φ_1 is completely straightforward but requires some patience with numerical factors (reader should check sign factors and numerical factors).

1. Calculate the current contraction term

$$j^\alpha\left[J_r^k\,\partial_\alpha h^r - J^\mu_{\ \alpha}\partial_\mu h^k\right]$$

and energy momentum tensor contraction term

$$T^{\alpha\beta}D_\beta\partial_\alpha h^k$$

and equate these terms. Effective two-dimensionality makes the explicit calculations relatively simple.

2. The equations for u and Φ in terms of $j^{\pm}$ read as

$$j^-(1-u_0^2) + j^+\epsilon_1\epsilon_2 = \{^{\ u}_{\Phi\ \Phi}\}\frac{K\epsilon_2^2}{2} \equiv X_1 \ ,$$

$$j^+\frac{1}{(1-u_0^2)}j^-\epsilon_2^2 = -2\{^{\ \Phi}_{u\ \Phi}\}K\epsilon_1\epsilon_2 \equiv X_2 \ ,$$

Here the notations $\epsilon_i = \omega_i R$ and $K = \omega_1\omega_2^2$ are used. Linear second order differential equations are in question with the right side serving as an inhomogenuity term.

3. One can solve j^+ and j^- from these equations to get

$$\begin{pmatrix} j^+ \\ j^- \end{pmatrix} = \frac{1}{\epsilon_1\epsilon_2^3-1} \times \begin{pmatrix} \epsilon_2^2 & -(1-u_0^2) \\ -1/(1-u_0^2) & \epsilon_1\epsilon_2 \end{pmatrix} \times \begin{pmatrix} X_1 \\ X_2 \end{pmatrix} \equiv \begin{pmatrix} Y_1 \\ Y_2 \end{pmatrix}$$

From this form one can see that j^- becomes singular at $u_0 = \pm 1$ as $1/(1-u_0^2)$ which means that light like vacuum current is generated. The physical interpretation is that vacuum charge density at these points which correspond to the boundaries of the solution acting as the source of the vacuum electric field is in question.

4. One can calculate $j^{\pm}$ by calculating the covariant divergence of the induce Kähler field in the lowest non-trivial order. The calculation gives the following expression

$$\begin{pmatrix} j^+ \\ j^- \end{pmatrix} = \omega_1 \begin{pmatrix} u_0\partial_+^2 u_1 + \epsilon_1\epsilon_2(1-u_0^2)\partial_+^2\Phi_1 \\ \omega_1\epsilon_2\partial_+^2 u_1 - \epsilon_1(1-u_0^2)\partial_+^2\Phi_1 \end{pmatrix}$$

5. For u_1 one finds the equation

$$\begin{aligned} \partial_+^2 u_1 \ &+\ \epsilon_1\epsilon_2^2\omega_1 u_0\partial_+ u_1 = \frac{1}{\omega_1} \times (Y_1 + \epsilon_1 Y_2) \\ &= \frac{\omega_2^2}{2}\frac{\epsilon_1}{\epsilon_1\epsilon_2^3-1} \times u_0 \times \left[-\epsilon_2^4(1-u_0^2) + \epsilon_1\epsilon_2(-2+\epsilon_1) - \epsilon_1^3\epsilon_2\frac{1}{1-u_0^2}\right] \ . \end{aligned} \tag{9.3.6}$$

This equation reduces to a first order differential equation for u_1 and one can solve it by variation of integration constants. The singularity at $u = \pm 1$ implies a logarithmic singularity of the derivative

$$\partial_+ u_1 \sim log(1-u_0^2)$$

but u remains finite as it should.

6. One can integrate Φ_1 from the second order inhomogenous and linear equation

$$\begin{aligned} \partial_2^+\Phi_1 &= \frac{1}{\epsilon_1\epsilon_2(1-u_0^2)}\left[j^- - \omega_2\partial_+^2 u_1\right] \ , \\ j^- &= \frac{\omega_1\omega_2^2\epsilon_1\epsilon_2}{2(\epsilon_1\epsilon_2^3-1)} \times u_0 \times \left[1 - \frac{2\epsilon_1^2}{1-u_0^2}\right] \ , \end{aligned} \tag{9.3.7}$$

once the solution for u_1 is known. Note that the most singular part corresponds to $u_0/(1-u_0^2)^2$ type term and one obtains logarithmic singularity also now.

9.3.5 Properties Of The Solution Ansatz

The form of the differential equations for the first order corrections allows to conclude that the North and South poles of the geodesic sphere S^2 (the points $u_0 = \pm 1$) correspond to singularities of the solution. Both the components of the induced metric and the induced Kähler form become singular at these points. This means that classical gravitation becomes important near these points. These points correspond in the lowest order approximation to the lines $x^+ = \pm 1/\omega_1 \equiv T$ plus possibly the lines obtained by continuing the solution by assuming that $x^- = constant$ lines define a motion identifiable constant rotation along the big circle from $\theta = 0$ ($x_+ = T$) to $\theta = \pi$ ($x_+ = -T$) continuing in the same manner to $\theta = 0$ at ($x = 2T$) and so on. Therefore gravitational effects induce a periodical behavior of the solution such that gravitational effects become strong at $x^+ = (2n+1)T$.

In the next order electric field is not constant anymore and vacuum current is generated. The contravariant component of electric field, being proportional to $1/\partial_+ u$ near singularity, vanishes at the singularity whereas the tangential component j^- of the vacuum current diverges. The vacuum current should generate coherent photons.

By a straightforward calculation one finds that the curvature scalar behaves as $R \propto 1/(1-u_0^2)$ at the singularities so that the energy density of vacuum becomes singular and could generate a coherent state of gravitons. Since Einstein tensor vanishes identically in two-dimensional case, the longitudinal components G^{++}, G^{--} and G^{+-} of Einstein tensor vanish. The components of Einstein tensor in transverse degrees of freedom are given by $G^{alpha\beta} = -g^{\alpha\beta}R/2$. Therefore the energy momentum tensor defined by Einstein's equations would involve only space like momentum currents. The singularity is amplified by the fact that field energy couples to the classical gravitation with coupling which is 10^8 times stronger than the ordinary gravitational coupling. The singularity might relate to the claimed gravitational anomalies associated with the scalar waves.

As already found, Einstein tensor and gauge current have no components in the direction of x^+. Energy-momentum tensor behaves as $1/det(g)^{3/2}$ at the end points of the interval $[-T, T]$ and thus vanishes. Therefore conservation laws allow to restrict the solution into the x^+ interval $(-T, T)$. This restricted solution defines geometrically a particle like structure moving in x^- direction but with fields moving in x^+ direction so that one would have rather exotic kind of particle-wave dualism. In accordance with the quantum-classical correspondence, one could interpret this as classical space-time representation of the particle wave duality and the solution would be a particular example of topological field quantization.

9.3.6 More General Solutions Representing Electric Field Of ConstantAction Density Are Possible

The solution ansatz just discussed represents a constant electric field in a region of space-time moving with ligth velocity in the direction of x^- coordinate. Also ordinary constant electric fied is a possible solution and is constructed iteratively in an essentially identical manner by starting from the solution ansatz

$$u = kz \ , \quad \Phi = \omega t \ . \tag{9.3.8}$$

Also now Kähler current vanishes in the lowest order and action density is constant so that lowest order field equations are satisfied. Higher order corrections are obtained using the ansatz $u_1 = u_1(z)$, $\Phi = \Phi_1(z)$. Minimal surface condition gives now essentially same kind of expressions for u_1 and Φ_1. Also now the singularities where gravitational interaction becomes strong are at $u = \pm 1$ and one can select the solution to represent a membrane like structure with thickness $L = 2/k$.

Cell membrane space-time sheets are good candidates for the realization of this kind of solutions. If so, one might expect that classical gravitational effects become important at the boundaries of the cell membrane. More generally, bio-systems are electrets and the proposed solution type might provide a fundamental model for bio-electrets. In particular, electrogravitic effects due to the energy of the classical electric field might be of importance.

This observation relates interestingly to the sol-gel phase transitions occurring inside cell. In these transitions large scale bound states of water molecules are formed and could make possible macro-temporally quantum coherent systems able to perform quantum computations in time scales of order say .1 seconds. These bound states would be characterized by spin glass degeneracy broken only by the classical gravitation and spin glass degeneracy would make these bound states long-lived. In the case of the proposed solution ansätze spin glass degeneracy corresponds to the canonical symmetries of CP_2 generating new solutions representing constant electric field.

Also M^4 diffeomorphisms are symmetries of the field equations broken only by the classical gravitation. Approximate diffeomorphism invariance means that one obtains solutions for which the lines of electric flux are curved and only the action density stays constant. In the case of magnetic flux tubes this symmetry makes possible curved magnetic flux tubes. Both electric fields and the magnetic flux tubes are fundamental for the TGD based model of living matter and relate deeply to the electric-magnetic duality symmetry and to the quantum criticality predicting that magnetic and electric space-time regions having opposite signs of Kähler action play a role similar to the ice and water regions at critical point of water, are important physically.

9.4 Time Mirror Mechanism

As explained in the introduction, time mirror mechanism (see **Fig.** `http://tgdtheory.fi/appfigures/timemirror.jpg` or **Fig. ??** in the appendix of this book) is excellent candidate for the fundamental bio-control mechanism allowing magnetic body to act as an intentional agent and control biological body. For a physicist living in Newtonian world the idea that "me" corresponds to a field structure of an astrophysical size is of course difficult to swallow. p-Adic physics as physics if intentionality and cognition however supports this view strongly: what is infinitesimal p-adically (cognitively) is literally infinite in the real sense so that cognition and intention are cosmic phenomena. In this section the possible role of scalar wave pulses in the realization of intentional action is considered. Also some aspects related to the role of time mirror mechanism for consciousness are discussed and it is shown that Libet's experiments related to the strange delays of conscious experience provide support for both time mirror mechanism and the notion of magnetic body.

9.4.1 Scalar Wave Pulses As Producers Of Phase Conjugate Waves And Time Mirror Mechanism

If one wants to produce negative energy photons, one must break the second law of thermodynamics. TGD predicts that in a given n-ary p-adic length scale $L(n,k)$ (size of the space-time sheet) this is possible below the n-ary p-adic time scale $T(n,k) = L(n,k)/c$. One must only produce pulses having duration shorter than the p-adic time scale $T(n,k)$. Scalar wave pulses are excellent candidates this kind of pulses since they accelerate the current carriers, which have ended up to the space-time sheet of the scalar wave pulse, and during this period they can emit negative energy photons as "acceleration radiation" with quantized frequencies $f_n = n/T_p$, T_p the duration of the scalar wave pulse. If the pulses correspond to their own space-time sheets dissipation is negligible and the intensity of acceleration radiation is maximal.

Scalar wave pulses could be produced by very rapidly rising electric pulses for which electronic currents are too slow to generate the voltage change between given points of circuit so that scalar wave pulse behaving like moving capacitor with vacuum charges at its electrodes must do the job. The duration of the scalar wave pulse would be most naturally the rising time τ_r of the pulse. Scalar wave pulse could be generated in a simple closed circuit. Assume that there is a voltage source V between points A and B and that A and B are connected to points A_1 and B_1 at which the wire branches to two wires going through a capacitor and current switch. When the current switch is off there is voltage V through capacitor. When the current is switched on, capacitor dis-charges very rapidly but the voltage between A and B must be still present. This is guaranteed if positive energy scalar wave pulse generates the voltage. The voltage through the capacitor is nullified by the absorption of negative energy scalar wave pulse coming from future and generated in the switching off process. In the geometric future the capacitor in turn absorbs the positive energy scalar wave pulse to generate the voltage V again.

An especially interesting situation arises when the energies of the negative photons radiated by the charged particles accelerated inside the scalar wave pulse correspond to the increment of a zero point kinetic energy for some charged particle when it drops to a larger space-time sheet. In this case the negative energy radiation could make possible time mirror mechanism by generating a cascade like dropping of charged particles and an amplified emission of positive energy photons. In case of nerve pulse the rising time of the pulse would be a good candidate for the duration of the scalar wave pulse.

In many-sheeted space-time particles topologically condense at all space-time sheets having projection to given region of space-time so that this option makes sense only near the boundaries of space-time sheet of a given system. Also p-adic phase transition increasing the size of the space-time sheet could take place and the liberated energy would correspond to the reduction of zero point kinetic energy. Particles could be transferred from a portion of magnetic flux tube portion to another one with different value of magnetic field and possibly also of Planck constant h_{eff} so that cyclotron energy would be liberated.

9.4.2 Bio-Systems And Unipolar Pulses

One might think that besides Tesla also bio-systems might have invented the sharp pulses as a way to break second law temporarily and produce negative energy topological light rays crucial for all basic mechanisms in TGD based quantum biology and theory of consciousness. Perhaps one function of nerve pulse is to produce phase conjugate waves and perhaps nerve pulse can be switched on by a scalar wave pulse reducing the membrane potential below the critical value.

This suggests the existence of biological variants of binary coils. Bio-systems are full of binary structures such as DNA double strand and cell membrane (consisting of two lipid layers). It is tempting to think that DNA double strand is a variant of bi-filar coil in which scalar wave pulses propagate along strand (associated with say gene) and return along the conjugate strand. Also now the effective inductance of the system would grow from zero to some maximum value and return back to zero and phase conjugate light would be generated. As a matter fact, the TGD based model for bio-photons lead to the hypothesis that the strand/conjugate strand generates positive/negative energy MEs and that these MEs move in opposite directions along strands [K49].

9.4.3 Sensory Perception, Motor Action, And Time Mirror Mechanism

TGD view about sensory perception differs dramatically from that of the standard neuroscience in that sensory organs are carriers of basic sensory representations and the magnetic body rather than body or brain is the experiencer with which we can identify ourselves.

Sensory organs as seats of qualia

According to the music metaphor, sensory organs are responsible for the music whereas brain writes it into notes by building symbolic and cognitive representations communicated to the magnetic body. Back projection to the sensory organs is an essential aspect of this process and is discussed in the article "Quantum model of sensory receptor" of [L1]. Sensory perception at the level of magnetic body involves the generation of negative energy MEs entangling with sensory organs involving possibly also brain as an intermediate entangler.

The assumption that sensory organs are carriers of the sensory representations entangling with symbolic representations realized at the level of cortex does not mean any revolution of neuroscience, just adding something what is perhaps lacking [K41].

Neuronal/symbolic level would do its best to symbolically represent what occurs naturally at the level of qualia. Color constancy could be understood as a basic characteristic of color qualia represented symbolically at the neuronal level. Center-surround opponency for the conjugate colors is the neural counterpart for the contrast phenomenon in which the boundary for a region of the perceptive field with a given color carries the conjugate color (black-white opponency associated with the luminance is only a special case of this). The contrast phenomenon at the level of visual qualia could derive from the vanishing of the net color quantum numbers for the electrodes of the retinal color capacitors.

The basic prediction is the presence of the back projection at least in the sensory modalities in which hallucinations are possible. MEs with MEs mechanism is the most natural candidate for realizing the back projection, negative/positive energy MEs would realize the back projection based on quantum/classical communications, and the capacitor model of the sensory receptor can be applied to model photoreceptors and retina. This picture integrates nicely with the various speculations about the role of the ciliary micro-tubules in vision. The obvious question is how the presence and character of the back projection reflects itself in the structure of the sensory pathways and sensory organs.

Basic facts about how gastrulation and neurulation proceed during the development of the embryo, lead to testable hypothesis about the character of the back projection for various sensory modalities. According to the hypothesis, one can speak about "brain senses" and "skin senses" according to whether the back projection is based on quantum or classical communications.

How motor action differs from sensory perception?

There is a deep similarity between sensory perception and motor action in TGD framework, the basic difference being that classical signals propagate in different direction in CNS. Motor action is initiated by the magnetic body by the sending of negative energy to motor organs by generating negative energy MEs, and proceeds by similar processes backwards in the geometric time to the level of brain and magnetic body, very much like an instruction of a boss at the top of organization to the lower levels of hierarchy and induces lower level instructions. The analogy with computer program calls (quantum communications, desires) and their executions (classical signals, actions) is also obvious. Also classical signals from the magnetic body to the body and brain are possible. Similar picture applies to sensory perception with motor organs replaced by sensory organs.

Sensory *resp.* motor imagination differ from sensory perception *resp.* motor action only in that the magnetic body entangles with some higher level of CNS. Therefore there is no danger that imagined motor action would become real or that imagined sensory perception would be experienced as real. This picture is in accordance with the idea of quantum credit card implying maximal flexibility, and with respect to the geometric time would mean that motor actions are only apparently initiated from the brain.

Time delays of consciousness: experiments related to the active role of consciousness

Libet has carried out classical experiments about active and passive aspects of consciousness [J40, J13]. It has gradually become clear that these experiments can be interpreted as a support for the identification of "me" as the personal magnetic body. The first class of experiments [J74, J13] is related to the active role of consciousness. For example, the human subject moves his hand at free will. What happens is that neurophysiological processes (changes in EEG, readiness potential) start $T_1 = .35 - .45$ seconds before the conscious decision to move the hand whereas the awareness about the decision to move the hand comes $T_2 = .2 - .1$ seconds before the hand movement. Decision seems to be followed by the action rather than action by decision! This is in apparent accordance with the point of view that consciousness is indeed a passive spectator and the act of free will is pure illusion. What is interesting from the p-adic point of view, is that the most plausible estimates for the time delays involved are $T_1 \simeq .45$ seconds and $T_2 = .1$ seconds [J74]. T_1 is very near to the p-adic time scale $T(6, 43) = .4$ seconds and T_2 to the fundamental p-adic time scale $T(2, 127)$ defining the duration of the memetic codon.

One can imagine two explanations for the paradoxical findings. The explanations turn out to be mutually consistent.

1. The geometric past changes in quantum jump

Quantum jump between histories picture explains the time delays associated with the active aspect of consciousness nicely and also gives an example of two kinds of causalities.

1. The simplest assumption is that the subjective experience of the hand movement corresponds to the moment, when subject person experiences that hand movement occurs.
2. The space-time surfaces (resulting as the final state of quantum jump) associated with the new quantum history differ in a detectable manner from the old quantum history already before the moment of hand movement since otherwise the new space-time surface would contain an instantaneous and discontinuous jump from the initial to final body configuration, which is not allowed by field equations. Same argument applies to the state of brain. $\Delta T \sim .5$ seconds seems to be the relevant time scale.

3. The attempt of the experimenter to be objective means that in an ideal experiment the observations correspond to the new deterministic history in the associated quantum jump and hence experimenter sees neurophysiological processes as the (apparent) cause of the hand movement with respect to geometric time. With respect to the subjective time the cause of the hand movement is the decision of the subject person.

2. Motor action is initiated from the magnetic body and proceeds to shorter length scales in reversed direction of geometric time

The vision that motor actions are initiated by magnetic body by feeding negative energy to motor organs and proceed upwards in CNS in a reversed time direction is in accordance with the idea of quantum credit card implying maximal flexibility and would mean that motor actions are only apparently initiated from brain. Motor organs send negative energy MEs to get metabolic energy, say to cortex. If there is lapse $\sim .5$ seconds involved then the observed lapse would find explanation. This view concretizes the idea about the editing of the geometric past and is consistent with the more general explanation discussed above.

This view about motor action means that it proceeds from long length scales to short ones whereas in the standard neuroscience view motor motor action would be planned and initiated in the brain and proceed to the level of motor organs, from short to long length scales. This certainly seems to be the case if one looks only the classical communications (say nerve pulse patterns). The extreme coherence of and synchrony of motor activities is however in conflict with this picture: neuronal communications are simply too slow to achieve the synchrony. This has been emphasized by Mae-Wan Ho [I82]. Since quantum communications proceed backwards in geometric time, classical signalling such as nerve pulses from brain to motor organs are actually reactions to the initiation of the motor action from the magnetic body.

Strange time delays of consciousness: experiments related to the passive role of consciousness

Libet's experiments [J40] about the strange time delays related to the passive aspects of consciousness have served as a continual source of inspiration and headache. Every time I read again about these experiments, I feel equally confused and must start explanations from scratch.

What is so important and puzzling is that the backwards time referral of sensory experience is so immensely long: about.5 seconds. The time taken for nerve pulses to travel through brain is not more than .01 seconds and the time to arrive from sensory organs is at most.1 seconds (for axon with length of 1 meter and very slow conduction velocity 10 m/s). For the purposes of survival it would be advantageous to have a sensory input with a minimal time delay.

Why then this long delay? TGD inspired answer is simple: the "me" does not correspond to the material body but to the magnetic body associated with the physical body, and is analogous to the manual of electronic instrument, kind of a monitor screen to which sensory, symbolic and cognitive representations are projected by quantum and classical communications. Since the size of the magnetic body is measured using Earth's circumference as a natural unit, the long time lapse results from the finite velocity of light.

The following explanation is a variant of the model of the sensory representations on the magnetic canvas outside the body and having size measured by typical EEG wave lengths [K52]. The basic sensory representations are realized at the level of the sensory organs and entangled with magnetic body whereas symbolic representations are either shared as mental images by or communicated classically to the magnetic body. This differs from the original scenario in which sensory representations were assumed to result by classical communications from brain to the magnetic body.

1. Communications from brain to magnetic body

One must consider two kinds of communications from body to magnetic body corresponding to positive energy MEs generated by at least brain and negative energy ME sent by magnetic body to at least sensory organs. The assumptions are following.

1. Negative energy MEs bound state entangle the magnetic body with the sensory representations realized at the level of sensory organs, and constructed using back projection from brain

and possibly also from higher levels. Fusion and sharing sensory mental images is involved. Also the classical communication of memories to magnetic body could be involved with the build up of sensory and symbolic representations at the magnetic body. In both cases sensory representations are memories with the same time lapse determined by the length of the MEs involved, a fraction of second typically if the magnetic body is of an astrophysical size. During sensory and motor imagination magnetic body entangles by negative energy MEs with some higher level of CNS.

2. Symbolic representations in brain can entangle with the sensory representations entangling in turn with the magnetic body so that CNS defines tree like structure with roots corresponding to sensory organs and branches and leaves corresponding to the higher levels of CNS. Direction of attention selects some path along this tree somewhat analogous to the path defining computer file in some subdirectory.

3. Symbolic representations of the perceptive field can be projected to the magnetic body using also classical signalling by positive energy MEs with phase velocity in a good approximation equal to the light velocity. For instance, if perceptive field contains something important, classical signal to the magnetic body could induce the generation of negative energy MEs turning attention to a particular part of perceptive field. Projection to the magnetic flux tubes of the Earth's magnetic field is possible. The spatial direction of the object could be coded by the direction of ME located in brain whereas its distance could be coded by the dominating frequency of ME which corresponds to a magnetic transition frequency which varies along the radial magnetic flux tubes slowly so that place coding by magnetic frequency results. Field pattern could be realized the coding of information to bits in some time scale, perhaps even in the time scale of millisecond associated with the memetic code. Positive energy MEs generated by brain realize the representation and this implies time delay. In the original model it was assumed that the direction and distance of the object of perceptive field are coded as direction and distance at the magnetic body. The representations are expected to be rather abstract, and it might be enough to perform this coding at the level of magnetic bodies associated with the sensory organs.

2. Libet's findings

Consider now Libet's findings. According to the summary of Penrose in his book "Emperor's New Mind" these experiments tell the following.

1. With respect to the psychological time of the external observer subject person becomes conscious about the electric stimulation of skin in $\sim .5$ seconds.

2. Subject person feels no time delay. For instance, she can tell the time clock shows when the stimulus starts. This can be understood if the sensory representation, which is basically a geometric memory, takes care that the clock of the memory shows correct time: this requires backwards referral of about .5 seconds.

3. One can combine an electric stimulation of skin with the stimulation of the cortex. The electric stimulation of the cortex requires a duration longer than .5 seconds to become conscious. If the stimulation of the cortex begins (with respect to the psychological time of the observer) for not more than .5 seconds before the stimulation of the skin starts, both the stimulation of the skin and cortex are experienced separately but their time ordering is experienced as being reversed! If the cortical stimulation generates sensory mental image at sensory organ by back projection then one could understand the change of the time ordering as resulting from.5 second lapse for the generation of back projection.

4. If the stimulation of the cortex begins in the interval $.25 - .5$ seconds after the stimulation of the skin, the stimulation of the skin is not consciously perceived. This effect is known as a backward masking. From the source it is not clear whether a minimal duration of .5 seconds of cortical stimulation is required for backward masking.

3. Explanation of Libet's findings

Consider now how one could understand these strange findings in the proposed model.

1. Visual and tactile sensory inputs enter into cortex essentially simultaneously so that the construction of symbolic representations at magnetic body is possible. The projection to the magnetic canvas by positive energy MEs and the generation of the magnetic quantum phase transition might quite well explain the time lapse of .5 seconds. The symbolic representation could contain also information about where to direct sensory attention. After this time interval negative energy ME possibly directing the attention to a particular part of the perceptive field would be generated and induce sharing of mental images .5 seconds in the geometric past. Note that this would automatically guarantee that symbolic and sensory representations at the magnetic bodies of sensory organs correspond to the same value of the geometric time.

2. The stimulation of the cortex lasting at least .5 seconds would generate a back projection to sensory organs. The minimal duration of .5 seconds for the cortical stimulation would seem rather natural in order to avoid back projections due to random neuronal fluctuations. This would explain why the temporal order of the sensory experiences generated by cortical and skin stimulation is reversed when cortical stimulation starts before the skin stimulation.

3. Consider now how the backwards masking could be understood. The cortical stimulation could generate a negative energy ME sent to the sensory organ and editing its geometric past at temporal distance of.5 seconds and depleting energy resources so that sensory organ cannot receive negative energy ME from magnetic body during the period of the cortical stimulation. Magnetic body would become sensorily blind to the input from the corresponding point of skin. Sensory blinding could be a clever manner to signal to the magnetic body that back projection is to be expected.

The stimulated point of the cortical map would share the sensory mental image instead of the magnetic body and also give rise to a back projection: sensory mental image would be conscious to cortex but not to us! Magnetic body and cortex could be seen as competitors for resources in this kind of situation. Perhaps the electric stimulation induces some kind of neuronal starvation and forces the neuron to generate negative energy MEs entangling it with the sensory organs.

9.5 Did Tesla Discover How To Change The Arrow Of Time?

After having made the inventions providing much of the basis technology for the modern electricity based society, Tesla used the rest of his life to study the strange phenomena related to sharp electric pulses. Tesla became convinced that pulse like rays carrying longitudinal electric fields exists although Maxwell's theory does not allow them. Needless to say, Tesla's findings were not taken seriously by the scientific establishment. On the other hand, for the developers of so called free energy technologies Tesla has remained a magic figure. To me it has gradually become clear that it might be possible to formulate the visions of Tesla using the language of modern physics, and the final breakthrough came with a discovery of a mechanism generating what I have used to call negative energy topological light rays having phase conjugate laser waves as physical counterparts.

Negative energy topological light rays provide the fundamental control mechanism in the TGD based model of living matter and appear in practically every mechanism of consciousness as a basic step. This is however not yet the whole story. One should also identify mechanisms allowing to control the generation of the negative energy topological light rays: direct transformation of p-adic MEs to negative energy MEs is probably not enough. The solution to the problem came from a quite unexpected direction. It was the attempt to understand the physics behind the visions of Tesla which led to an identification of a very general mechanism of this kind.

Phase conjugate laser waves break second law of thermodynamics and this is possible in TGD Universe below the p-adic time scale characterizing the system. Therefore short pulses are ideal for this purpose. Depending on the situation, electric pulses in electric circuits typically force the charge carriers to accelerate or decelerate. During deceleration positive energy photons are emitted as brehmstrahlung whereas during acceleration charges emit negative energy photons in order to receive energy. Thus generation of pulses provides a mechanism to generate negative energy topological rays which in turn serve for various control purposes. TGD indeed predicts the existence of scalar wave pulses propagating in vacuum with light velocity and carrying longitudinal electric fields.

One can understand the basic findings of Tesla at qualitative level in TGD framework and there are strong reasons to believe that Tesla was right after all. This of course raises the question how it is possible that the scientific community with all its technology remained silent about the findings of Tesla for an entire century. Experimentalists must have made occasional encounters with the phenomena reported by Tesla. Are modern experimentalists conditioned to take theorists quite too seriously?

9.5.1 Discussion Of The Basic Ideas And Concepts

Do negative energy space-time sheets have counterparts in quantum field theory?

Negative energy topological light rays seem to correspond to phase conjugate laser waves. In particular, the experiments of Feinberg [D6] are consistent with the transparency of matter for phase conjugate laser beams with photon energies above thermal energy. In optics phase conjugation requires optically non-linear system [D13]. For instance, in usual hologram the matter is optically non-linear in the sense that dielectric constant depends on the external electric field so that the electromagnetic radiation induces a change of the refraction coefficient which in turn codes for the hologram.

The dynamics of classical fields is indeed extremely nonlinear in TGD: the topological field quantization is one of the most dramatic outcomes of this non-linearity. Whether the phenomenological models for phase conjugate waves and for their generation are enough in TGD framework is an open question. The mechanism based for the generation of negative energy topological light rays based on short pulses to be discussed in this section does not seem to reduce to the framework of non-nonlinear optics.

There are also questions of principle involved.

1. Is phase conjugation properly understood in quantum field theories?

At the level of quantum physics negative energy photons would correspond to a system quantized in such a way that both bosonic and fermionic annihilation and creation operators have changed their roles. Negative energy photons and fermions do not correspond to (non-existing) “anti-photons” and anti-fermions. Using the terminology of Dirac’s bra-ket formalism: negative energy systems are like bras if positive energy photons are kets. Kets and bras correspond to Hilbert space and linear functionals defined in it. The space of bras is actually not equivalent with that of kets but in a well defined sense a more general concept. This conforms with the role of negative energy space-time sheets in TGD inspired theory of consciousness.

In quantum field theories time reversal transforms creation operators for fermions to creation operators for anti-fermions. Vacuum state is not changed. Time reversal in TGD sense would transform ket vacuum to bra vacuum so that the earlier creation operators annihilate the new vacuum state and genuine negative energy states result. This would suggest that negative energy states are something genuinely new and a genuine outcome of the many-sheeted space-time concept allowing either bra and ket type vacuum at a given space-time sheet. This difference might relate to matter-antimatter asymmetry whose origin is one of the deepest problems of cosmology. Perhaps dynamics favors space-time sheets containing negative energy matter instead of antimatter.

2. Phase conjugation and irreversibility

One interesting aspect associated with negative energy topological light rays is that they seem to be irreversible systems. On the other hand, phase conjugation can be used to eliminate perturbations on signal caused by thermal noise since the evolution proceeds from perturbed to non-perturbed signal. This could be seen as an objection against TGD based interpretation stating that topological light rays are essentially non-dissipative structures of classical physics.

The objection can be circumvented. Classical-quantum correspondence implies that space-time physics mimics also the dissipative aspects of quantum dynamics defined by quantum jump sequences. The classical non-determinism of the basic variational principle makes this possible. Classical fields are non-dissipative structures are even able to represent information about dissipation, analogous to a written text telling a story about growth, flourishing, and decay. In fact, in TGD framework space-time itself provides symbolic classical representations for quantum jump sequences determining the subjective, experienced reality. The implications of this representative aspect for biology are highly non-trivial. For instance, phase conjugate waves could provide a fundamental mechanism of healing and error correction.

Matter-antimatter asymmetry, phase conjugation for fermions, and new energy technology

If photons with negative energies are allowed, it is difficult to deny the possibility of fermions with negative energies. The possibility of having both signs of energy suggests an elegant solution to the problem of matter-antimatter asymmetry and a powerful new energy technology.

1. The standard second quantization of Dirac spinors postulates that ground state is annihilated by annihilation operators for fermions and anti-fermions. One can construct explicitly the state annihilated by annihilation operators. Suppose that there is state which is not annihilated by any annihilation operator and apply the product of all annihilation operators to this state. Electrons and positrons represent holes in this sea and are created by applying creation operators. The states have positive energy with respect to the ground state. The aesthetic problem of this quantization is that ground state has an infinitely high negative energy.

2. In TGD framework one could change the role of creation and annihilation operators so that the ground state would be obtained by applying the product of all creation operators to vacuum. This state would have infinite positive energy. Fermions and anti-fermions would be holes in Dirac sea of positive energy and behave as negative energy quanta. One might expect that these two quantizations correspond to two different time orientations for the space-time surface.

1. Two ways to circumvent the infinite vacuum energy

The infinite vacuum energy is definitely something very unsatisfactory, and one should overcome this problem somehow. The most elegant and predictive variant of TGD inspired cosmology assumes that the net energy of the Universe vanishes so that the universe could have been created intentionally from vacuum (and be created again and again in each quantum jump). The vanishing of the total energy follows automatically if one poses the condition that the energy flow through the light cone boundary ($H = M^4_+ \times CP_2$) vanishes. This requires that also fermionic vacuum energies cancel each other. There are two ways to achieve the cancellation.

1. If positive and negative energy space-time sheets are always created in a pairwise manner their vacuum energies could compensate each other, at least so if some additional conditions are satisfied. The success of elementary particle physics requires that this mechanism is at work in elementary particle length scales.

2. Vacuum energies could also cancel each other for each space-time sheet separately. This is achieved if the roles of creation and annihilation operators for either fermions or anti-fermions are exchanged. This implies automatically matter antimatter asymmetry since either fermions or anti-fermions would have negative energies. This option could be realized in long length scales and explain the absence of antimatter from the Universe as absence of positive energy antimatter. It would thus seem that all four ground states states are in principle possible and that the ground state characterizes the phase of matter.

2. Zero energy vacuum is matter-antimatter asymmetric

Consider now in more detail the latter option 2) assuming for definiteness that it is anti-fermions for which the roles of creation and annihilation operators are exchanged. The ground state is obtained by applying the product of all fermion annihilation operators and anti-fermion creation operators to vacuum. Fermions represent holes in a completely filled negative energy Dirac sea and have positive energy. Anti-fermions represent holes in positive energy Dirac sea and have thus negative energy. In this ground state annihilation of photon pair is possible only to an fermion with positive and anti-fermion with negative energy.

Obviously the state is matter-antimatter asymmetric since anti-fermions cannot appear as positive energy holes. Negative energy antimatter could be present but could have remained invisible. For instance, Pauli Exclusion Principle would make the scattering of negative energy anti-fermions impossible in the case that there are not sufficiently many holes in the sea. The same occurs for condensed matter electrons below the surface of the Fermi sphere. Even in the case that negative energy anti-fermions are present abundantly, they might have escaped detection. Due to the prevailing dogmas, no-one has tried to detect signatures for the scattering of negative energy anti-fermions or two photon annihilation to a pair of positive energy fermion and negative energy anti-fermion.

3. Creation of matter from vacuum by annihilation of laser waves and their phase conjugates?

The possibility of negative energy anti-fermions suggests a new energy technology. Photons and their phase conjugates with opposite energies could only annihilate to a pair of positive energy fermion and negative energy anti-fermion. Vacuum could effectively serve as an unlimited source of positive energy and make creation of matter from nothing literally possible. The idea could be tested by allowing laser beams and their phase conjugates to interact and by looking whether fermions pop out via two-photon annihilation. Fermion-anti-fermion pairs with arbitrarily large fermion masses could be generated by utilizing photons of arbitrarily low energy. The energies of the final state fermion is completely fixed from conservation laws so that it should be relatively easy to check whether the process really occurs. Generalized Feynman rules predict the cross section for the process and it should behave as $\sigma \propto \alpha^2/m^2$, where m is the mass of the fermion so that annihilation to electrons is the best candidate for study. Bio-systems might have already invented intentional generation of matter in this manner. Certainly the possible new energy technology should be applied with some caution in order to not to build a new quasar!

4. New view about inertial and gravitational energy

A longstanding puzzle of TGD inspired cosmology has been the conservation of energy implied by Poincare invariance which seems to be in conflict with the non-conservation of gravitational energy. It took time to discover the natural resolution of the paradox. In TGD Universe matter and antimatter have opposite energies and gravitational four-momentum is identified as difference of the four momenta of matter and antimatter (or vice versa, so that gravitational energy is positive). The vanishing of the inertial energy density in cosmological length scales is the proper interpretation for the fact that Robertson-Walker cosmologies correspond to vacuum extremals of Kähler action. The assumption that the net quantum numbers of Universe vanish is maximally predictive and allows to get rid of unpleasant philosophical questions like "What are the net conserved quantum numbers of the Universe".

That particle reactions can correspond to a creation of zero energy states from vacuum is consistent with the crossing symmetry of particle physics and the proposed identification of gravitational energy in absence of appreciable annihilation of positive and negative energy matter creates the illusory western view about objective reality possessing positive inertial energy. The classical non-determinism of vacuum extremals carrying non-vanishing gravitational energy density can be interpreted as being space-time correlate for the fact that Universe is partially engineered.

Pulses, Tesla transformers, and bi-filar coils

The function of quite a many free energy systems involve sharp pulse sequences. Often the bi-filar invented by Tesla [H21] are used to produce magnetic pulses. Together with general TGD based vision this leads to a theoretical picture allowing to understand the visions of Tesla theoretically.

1. The vision briefly

A very concise summary of the model goes as follows.

1. The basic prediction of TGD are negative energy topological light rays propagating backwards in geometric time. They can be accompanied by self-generated negative energy photons since in general case topological light rays carry light like vacuum 4-current. The interpretation as

counterparts of phase conjugate laser waves [D13] seems to make sense. A sequence of pulses carrying constant electric field forces charge carriers to accelerate repeatedly provided the frequency of the pulses is sufficiently low for charged to come at rest. A decelerating system emits its energy as positive energy photons whereas the accelerating system might receive its energy by emitting negative energy photons if deceleration and acceleration are genuine time reversals of each other.

2. Negative energy photons are absorbed by any system which contains (possibly many-sheeted) population inverted lasers with appropriate excitation energy when bosonic particles return to their ground states. If sufficiently many bosonic particles return to the ground state, a phase transition return to the ground state occurs and is analogous to induced emission. Large number of positive energy photons are generated and a weak negative energy control signal is amplified to much stronger positive energy signal. The resulting energy is identifiable as "free energy".

The generation of negative energy photons breaks second law. In TGD Universe second law however holds true at a given p-adic length scale only in time scales longer than the corresponding p-adic time scale. This means that field patterns having a duration below the relevant p-adic time scale can appear as negative energy topological light rays. Sharp electric pulses carrying a constant electric field are ideal in this respect.

Suppose that electric pulses are fed into a bi-filar coil and induce currents in the primary coil. Due to the large mutual inductance between loops of the primary and secondary coils composing the bi-filar coil, the current generated by the pulse in the primary loop is transmitted inductively to the nearby second loop, which in turn generates a positive feedback to primary. Thus the current is amplified and the propagation of the electric pulse induces a propagation of large rapidly varying currents in coils rotating in opposite direction so that the magnetic flux inside the bi-filar coil is small. First of all, this means that the sequence of electric pulses induces a currents through the two components of the bi-filar coil by effectively reducing the inductance of the coil. Secondly, the amplification of the current means amplified acceleration of the charge carriers optimal for the generation of negative energy photons as time reversed brehmstrahlung.

There are good reasons to expect that living matter has discovered the analogs of bi-filar coils long before humans, even before Tesla. Binary structures, such as DNA double strand and cell membrane consisting of two lipid layers, are good candidates for the counterparts of bi-filar coils and might play key control in the bio-control by serving as generators of negative energy photons in turn controlling the generation of positive energy photons.

2. Do electric pulses correspond to scalar wave pulses?

Interesting questions are related to the behavior of the electric field inside coils, in particular bi-filar coils. It seems that the expressive power of Maxwell's theory might not be enough here. It seems that the electric pulses propagating in any circuit could correspond to TGD counterparts of Tesla's scalar wave pulses.

1. The unipolar electric field is discontinuous at the ends of the pulse. In Maxwell's equations the rotor of the magnetic field equates to the sum of the current term j and the displacement current $\partial E/\partial t$. Either an infinitely sharp induction peak is allowed in the magnetic field or the displacement current must be compensated by the current term.

2. In Maxwell's electrodynamics a very high (ideally infinitely strong instantaneous) ohmic current would be needed to compensate the displacement current. This seems implausible. In TGD however vacuum charges and currents are possible. The electric square pulse is analogous to a moving capacitor and the charges of the capacitor plates could correspond to vacuum charges. At the level of space-time geometry the plates would correspond to propagating edges of the 3-surface. The induced electric field E_{rot} would induce a current pulse, whose direction would change in the middle of the magnetic pulse.

3. TGD indeed predicts the existence of scalar wave pulses [H21]. These pulses represent electric flux quanta, 3-surfaces inside which there is an almost constant longitudinal electric field. A capacitor moving with the velocity of light would be the analogy. These solutions

are not possible in Maxwell's theory. Because also the pulses moving in circuits are very similar, there is a large temptation to identify them as scalar wave pulses. In this case the effective propagation velocity is reduced below light velocity by the interaction with matter. Intuitively, the particles topologically condensed in the region of 3-surface representing the pulse make it massive and slow down the effective speed of propagation.

One might imagine that the scalar wave pulses could leak out of the system. For instance, this might happen if the second end of the coil is free. Tesla indeed reported a production of scalar wave pulses using a transformer whose primary coil was fed by a sequence of unipolar pulses. These pulses were amplified in a secondary coil in whose second end was free. Abnormally high voltage amplification with no current in secondary coil was reported [H13].

If the propagation velocity of the scalar wave pulse is light velocity, the time T would be the time taken by the pulse to propagate through the first half of the bi-filar coil: $T = Z/v$, where Z is the length of the wire in the bi-filar coil and $v = c$ is light velocity. For $v = c$ T would be 3.3 ns if the length of the wire is 1 meter. The interaction with the matter induces inertial effects and is expected to reduce the effective propagation velocity of the scalar wave pulse representing the electric pulse to $v < c$.

3. Could electric pulses in circuits correspond to separate space-time sheets?

Scalar wave pulses could correspond directly to the space-time sheets of electric flux quanta moving with light velocity predicted by TGD [K39] rather than being regions of constant electric field at the space-time sheet of wire. These flux quanta would move along wire and have flux tubes connecting the space-time sheet of the flux quantum with the boundaries of small co-moving holes associated with the circuit's space-time sheet. Charged particles could flow to the flux quantum along these bridges at the first end of the electric flux quantum, accelerate there practically without dissipation, and flow possibly also back at the second end of the flux quantum. The direction of the flow would be determined by the sign of the charge. This would allow anomalous acceleration of the charge carriers making it possible to emit negative energy photons up to energies determined by the voltage difference associated with the flux quantum. The lowering of the effective propagation velocity would be a genuine quantum effect based on the same mechanism as the lowering of the effect phase velocity of topological light rays.

Scalar wave pulse is like a moving capacitor and should be attracted or repelled by a real charged capacitor depending on the sign of its polarization. Therefore scalar wave pulse could be reflected from a capacitor and begin to move forth and back around the loop connecting the plates of the capacitor in a circuit. This is a testable effect. For instance, if bi-filar coil is coupled between the capacitor the pulse should move forth and back through it. If scalar wave pulses correspond to separate space-time sheets they can leak out of the system. The open ends of the secondary coils used by Tesla in his transformers might be the places where the leakage occurs. The emission of a new kind of radiation observed by Modanese and Pokletnov [H23] to accompany the discharge of a capacitor for which the negatively charged plate was super-conducting might represent the emission of scalar wave pulses [K39].

4. Sharp electric pulses as producers of phase conjugate waves?

Tesla transformers use ordinary coils as primary coils and open coil as a secondary coil. On basis of his experimental work Tesla claimed that Tesla transformers allow an anomalously high voltage amplification. Strangely, Tesla found no current in the secondary coil but the transformers induced charging of various metallic objects in large regions surrounding the transformer. This effect was able to penetrate even through Faraday cage.

The bi-filar coils discovered by Tesla [H21], which are fed by sharp unipolar electric pulses carrying constant electric field and analogous to moving capacitors, occur repeatedly in various free energy devices. This would suggest that bi-filar coils somehow produce phase conjugate laser waves (negative energy topological light rays accompanied by negative energy photons). These in turn would induce the dropping of bosonic charged particles to larger space-time sheets as a phenomenon analogous to induced emission when the intensity of negative energy photons is above some threshold. The challenge is to understand how square pulses propagating both in ordinary and bi-filar coils manage to produce phase conjugated light.

In many-sheeted space-time particles topologically condense at all space-time sheets having projection to given region of space-time so that this option makes sense only near the boundaries of space-time sheet of a given system. Also p-adic phase transition increasing the size of the space-time sheet could take place and the liberated energy would correspond to the reduction of zero point kinetic energy. Particles could be transferred from a portion of magnetic flux tube portion to another one with different value of magnetic field and possibly also of Planck constant h_{eff} so that cyclotron energy would be liberated.

What is so special in the unipolar electric pulses circulating in bi-filar coils?

1. If one wants to produce negative energy photons, one must break the second law of thermodynamics. TGD predicts that in a given n-ary p-adic length scale $L(n,k)$ (size of the space-time sheet) this is possible below the n-ary p-adic time scale $T(n,k) = L(n,k)/c$. One must only produce pulses having duration shorter than the p-adic time scale $T(n,k)$. The sharp electric pulses are excellent candidates for this kind of pulses since they accelerate the charge carriers and during this period they can emit negative energy photons.

2. One class of important frequencies would correspond to harmonic multiples for the frequency $f = 1/T^E_{1/2}$, $T^E_{1/2} = T^E/2$, where T^E is the duration of the electric square pulse. A second important time scale is the time interval between the pulses which must be so long that the charges have time to come at rest. One expects that this time scale is of the order of $\tau = L/R$, where L and R characterize the (say) primary of the bi-filar coil. A third important time scale is the duration of the magnetic pulses generated in the pulsed bi-filar coil. The time T during which electric pulse propagates through the first half of the bi-filar coil is not so important as one might first think since mutual induction implies that the propagation of the electric pulse through the primary generates a propagation of a current also in the secondary. Besides these time scales important time scales are the time scales determined by the basic parameters L, C, R of the primary (secondary) of the bi-filar coil.

5. Bio-systems and unipolar pulses

One might think that besides Tesla also bio-systems might have invented the sharp pulses as a way to break second law temporarily and produce negative energy topological light rays crucial for all basic mechanisms in TGD based quantum biology and theory of consciousness. Perhaps one function of nerve pulse is to produce phase conjugate waves and perhaps nerve pulse can be switched on by a scalar wave pulse reducing the membrane potential below the critical value.

This suggests the existence of biological variants of bi-filar coils. Bio-systems are full of binary structures such as DNA double strand and cell membrane (consisting of two lipid layers). It is tempting to think that DNA double strand is a variant of bi-filar coil in which scalar wave pulses propagate along strand (associated with say gene) and return along the conjugate strand. Also now the effective inductance of the system would grow from zero to some maximum value and return back to zero and phase conjugate light would be generated. As a matter fact, the TGD based model for bio-photons lead to the hypothesis that the strand/conjugate strand generates positive/negative energy MEs and that these MEs move in opposite directions along strands [K49]
.

Could negative energy photons induce the transition to effective superconductivity?

The generation of negative energy photons involves temporary breakdown of the second law. Therefore the minimization of the resistance of the relevant part of the circuit, say bi-filar coil, should be favorable for the effect.

TGD based new physics might provide a possible mechanism reducing the resistance. If part of the current carrying electrons of the bi-filar coil drops down to the larger space-time sheets, where they propagate as Cooper pairs, the resistance of the system is reduced. The research group led by Hafedh Abdelmeik has found that the electric conductivity of axon grows by a factor of order 10 below a certain critical temperature, which is in the range 30-40 C of physiological temperatures [J30]. The TGD based model [K85] , [J31] explains the findings correctly at quantitative level.

A variant of this mechanism might be at work also in the case of electric circuits if appropriate conditions are satisfied.

1. The model for the realization of intentionality and motor activity relies on a process, which proceeds from long to short time and length scales, much like a desire for some action in an

organization proceeds from boss to the bosses at lower level. In the same manner a hierarchy of phase transitions could proceed from longer to shorter length and time scales and reduce the resistance and increase the upper limit for the energy of negative energy photons.

2. The pulses propagating in say bi-filar coil could produce already in the normal situation a sufficient amount of negative energy photons at low frequencies to induce a phase transition increasing the conductivity. The growth of the intensity of the negative energy photons emitted at higher frequencies could in turn induce a similar phase transition in a shorter p-adic length scale and corresponding to higher zero point kinetic energy. At every stage the negative energy photons could first cool the system so that the phase transition occurs more easily. The dropped Cooper pairs would in turn increase the portion of the supra current flowing at the ground state space-time sheet and thus conductivity.

9.5.2 Does The Model Explain The Basic Observations Of Tesla?

The basic vision of Tesla was that the sharp pulses involve physics not understood in the framework of Maxwell's theory. Tesla ended up with this vision on basis of certain empirical findings and it is interesting to find whether this observations could be understood in the proposed conceptual framework. In other words, could time reversal and the breaking of the second law below the p-adic time scales explain these findings.

Switching the current on as a time reversal for switching the current off

The basic observation of Tesla was that a sudden switching on of the current circuit produced strange phenomena. Besides sparks and light arcs strong charges were induced in the metal objects in environment. Physiological effects like electric shocks, pressure, sensations of heat, etc.. appeared. Also energy seemed to be liberated. The effects propagated through Faraday cage.

This kind of findings inspired Tesla to develop a technics to produce series of sharp pulses. In the system developed by Tesla, a magnet was repeatedly posed between the capacitor plates between which current was flowing to turn off the current for a moment. The outcome was a fast method for producing sharp current pulses. Tesla developed devices utilizing sharp pulses such as bi-filar coils and transformers, which produced much higher voltage in the secondary coil than one might have expected on basis of Maxwell's theory. The second end of the secondary coil was in freely in air and no current was observed at the end of the coil.

What was the source of these effects? The chapter "Rosetta Stone" in the book of Vassilatos [H13] contains a statement which gives a hint: when the current was switched on, the current carriers behaved as if they had collided with a wall and stopped for a moment. This sounds paradoxical since it is what one might expect to happen when the current is switched off so that resistance suddenly increases. Now just the opposite happened.

A possible solution to the paradox is provided the reversal of geometric time. If the switching on of the current is time reversal of the switching off, the initial situation could be that the system is in a state resulting after closing off of the circuit and it might contain very high charge densities. The resulting high electric fields could even induce the evaporation of the wire. This would mean that the second law of thermodynamics would enter the game and the process would not proceed in the desired manner. In fact, it is not necessary to assume even this as following argument demonstrates.

Time reversal allows to understand what happens in the case that the time reversed process proceeds.

1. When the current is switched off, charge carriers decelerate and emit their energy as positive energy photons. When the current is switched on, charges accelerate and get their energy by emitting negative energy photons. If the system starts from a situation in which charges have "collided with a wall" the amount of energy needed is especially high. This is however not necessary.

2. Condensed matter like water or biological matter are full of population inverted many-sheeted lasers. At certain resonance frequencies corresponding to the differences of the zero point kinetic energies negative energy photons induce phase transitions discharging the population

inversion of the many-sheeted laser. From certain space-time sheets charged "drop" to large space-time sheets, say magnetic flux tubes. A cascade of positive energy photons is liberated and manifests itself as "free energy".

3. The metallic (for instance) objects receiving negative energy photons lose net charge to the large space-time sheets and generate a net charge of opposite sign so that a high voltage with respect to the environment is generated. This indeed was found by Tesla to occur, and the charge definitely did not originate from the circuit generating the effect. This in fact led Tesla to postulate that ether carrying the charges was emitted in the process. Process can occur in a wide region since negative energy photons of sufficiently high energy do not respect Faraday cage. The reason is that there is not system able to absorb them and thus drop to a lower energy state. The net charge is developed because the negative energy topological light rays act as "bridges" along which the charge can move between space-time sheets. Since there is an electric field in the direction of the bridges, the charges move only in second direction fixed by the sign of the charge.

4. Switching of the current on acts as a control process which switches much larger process in environment using negative energy photons. Basically the process is due to the inherent instability of the many-sheeted space-time. What happens is analogous to a transition from a bottom of potential well in a fractal spin glass energy landscape to a bottom of a deeper potential well. The process leads to a gradual transfer of matter to larger space-time sheets and cooling. The generation of larger space-time sheets means evolution of consciousness since the p-adic prime characterizing the space-time sheets identifiable as a kind of intelligence quotient grows in the process.

5. In order to maximize the intensity of negative energy photons and get as dramatic effect as possible, the parameters characterizing the pulse series can be optimized. The basic idea is that the system is rapidly shaken. This generates accelerations of opposite sign and the system is decelerated and accelerated in a fast tempo. There is however a limitation coming from the fact that charge carriers must have enough time to return to rest. We use instinctively this trick when we try to wake up a person who has lost consciousness.

Do scalar wave pulses appear also outside electric circuits?

The transients at the ends of voltage pulses correspond to a constant electric field propagating as scalar wave pulses with light velocity when the inertial quantum effects caused by the coupling with matter can be neglected. TGD allows solutions of field equations describing free scalar wave pulses with longitudinal electric field. Both positive and negative energy pulses are possible. The interesting question is whether the findings of Tesla necessitate the emission of free scalar wave pulses.

1. On basis of foregoing considerations it would seem that Tesla's scalar wave pulses outside the pulsed circuits are not necessary if one wants to understand the findings of Tesla. Of course, they could be involved.

2. In the chapter "Rosetta Stone" of the book of [H13] [H13] there is a summary of the properties of the electro-radiative event (ERE) observed by Tesla. It seems that one could understand them as effects induced by the emission of negative energy photons.

   In particular, ERE leaves wires and other circuit elements in a direction orthogonal to them. This favors strongly the interpretation in terms of topological light rays identifiable as TGD counterparts of ordinary radiation. In TGD topological light rays are however carriers of light like vacuum(!) 4-currents so that they generate coherent photons and can also carry Bose-Einstein condensates of parallel photons. The filament like light emitting structures orthogonal to metal coils could thus correspond to topological light rays. If they carry negative energy they should also generate coherent photons with negative energies.

3. Scalar wave pulses should leave an open wire in a direction parallel to the wire. The open secondary coil of Tesla transformer is a good candidate in this respect. From a capacitor the pulses should leave in a direction orthogonal to the capacitor plate and might reduce the

voltage of the capacitor by carrying quanta of electric flux which are very much like small capacitors themselves moving with a light velocity.

Why the radiation observed by Tesla was so difficult to detect using photography?

In the chapter "Rosetta Stone" of his book [H13] Vassilatos tells that although the radiation emitted by the Tesla's circuits was perceived both visually and experienced as physiological effects it was very difficult to detect it instrumentally, for instance by photographing: long deposit times were required.

The explanation for this might be very simple. Body and especially retina are full of population inverted many-sheeted lasers which can amplify a weak signal of negative energy photons to a much stronger signal consisting of positive energy photons. Ordinary photographic film very probably is not able to do this.

This idea is supported also by the TGD based model for sensory receptors [K41]. In TGD Universe sensory organs are the carriers of primary qualia like color, and one can say that brain only writes the sensory music to notes. Since brain processes the sensory input in a selective manner, a back projection from brain to sensory organs making virtual sensory experiences possible must be present. Negative energy photons provide the most elegant manner to realize this mechanism since bio-matter is transparent to them unless there are many-sheeted lasers tuned to the wavelength in question.

Photo receptors indeed contain a lot of mitochondria serving as energy plants of the cell and mitochondria are known to generate visible light which is not a mere side product of metabolism [I62]. This suggests that the signal consisting of negative energy photons is amplified to a positive energy visual signal in retina. This would occur during dreaming and explain rapid eye movements. The mechanism would make it possible to see using negative energy photons and even seeing even through physical objects using phase conjugated photons as the findings of Feinberg demonstrate [D13]. A camera using negative energy photons is a possible technological application. The camera would make it possible to take images through walls.

How Tesla transformer manages to yield so high voltage amplification?

Tesla reported that his transformers have an anomalously high voltage amplification. There are two cases to be considered corresponding to pulsed ordinary and bi-filar primary coils. In both cases it might be possible to understand Tesla's findings.

1. In the case of the ordinary coil the repeated acceleration of charges induced by electric pulses generates magnetic pulses inducing in turn voltage over the secondary coil. This is what also Maxwell's theory predicts. The emission of negative energy photons inducing the increase of conductivity and an anomalous amplification of the primary current would however mean that also the voltage induced in the secondary coil is anomalously high.

2. Only the net current flowing in the pulsed bi-filar coil induces electromotive force in the secondary coil. Thus the magnetic pulses should become much sharper than in the case of the ordinary coil. Already this implies that induce voltage along the secondary coil, being proportional to the time derivative of the magnetic flux, is very high during the short pulse. The currents induced by the electric pulse in the bi-filar coil increase also rapidly the resonance mechanism and eventually more or less compensate each other. The increase of conductivity is a further amplification mechanism possibly involved. By using a several primary bi-filar coils arranged around circle and having suitable phase lag, one could perhaps arrange a permanent anomalously large inductive effect.

Why no current was observed in the secondaries of Tesla transformers?

Tesla did not detect the emission of charge carriers from the open ends of the secondary coils of his transformers. What one would expect is that the voltage along the secondary generates a flow of charge carriers which are stuck to the open end and that part of them leaks out. Two factors are involved.

1. There was no current at atomic dissipative space-time sheets since the charge carriers were dropped to larger space-time sheets: perhaps at the flux tubes of the magnetic fields generated in the process or at the magnetic flux tubes of the Earth's magnetic field. An interesting possibility is that closed magnetic super conducting circuits involving primary and secondary coils are formed. The magnetic flux tubes could carry the charges also to environment and negative energy topological light rays might help to transfer the charge to the metallic objects in the environment.

2. Electric pulses correspond to a Tesla scalar wave pulses so that the surface charges associated with the ends of the pulse correspond to vacuum charges and vacuum currents. Therefore no ordinary charge carriers were associated with them.

9.6 Quantum Criticality, $1/F$ Noise And Consciousness

Criticality is a necessary prerequisite of control. Unless the system to be controlled has some critical variables in which small change induces large changes in the state of the system, control is very ineffective. The quantum criticality of TGD Universe indeed guarantees, not only the existence of macroscopic quantum systems, but also possibility of quantum control. What is encouraging is that quantum criticality can be correlated with $1/f$ noise, a phenomenon which has remained poorly understood in standard physics approach.

9.6.1 $1/F$ Noise

The so called $1/f$ noise deserves the often used attribute ubiqitous: it appears in widely different systems such as radio active decay, chemical systems, biology, fluid dynamics, astronomy, electronic devices, optical systems, network traffic and economics (references can be found in [D1]). An excellent article about $1/f$ noise in music by Martin Gardner in Scientific American [A26] gives a good grasp on the basic concepts. $1/f$ noise is less random than white noise with $1/f^0$ power spectrum and completely random correlation function and more random that Brownian noise having $1/f^2$ power spectrum (defined as the Fourier transform of the autocorrelation function $\langle A(t)A(t+T)\rangle$). In practice, the phrase $1/f$ noise is attributed also to power spectrum of form $1/f^\alpha$, $\alpha \simeq 1$.

There is no generally accepted explanation for $1/f$ noise. Power law with a negative value of exponent suggests that a system producing $1/f$ type noise is scaling invariant and has long range time and spatial correlations as a consequence. This suggests that fractal like structure is in question and Mandelbrot has indeed proposed that fractality is the basic underlying mechanism of $1/f$ noise. If this is the case, one however encounters the problem of identifying the underlying mechanism of fractality.

Critical systems are scaling invariant in the sense that regions of arbitrary large size of two phases can be present in the system. Critical systems are also known to exhibit fractal like structures. This suggests that criticality is the basic underlying cause of both fractals and $1/f^n$ type noise. The problem is however that critical systems are extremely unstable: arbitrarily small perturbation can change the value of the critical parameter (such as temperature) so that criticality is lost. This is certainly not in accordance with the universality of $1/f$ noise and of fractals.

The paradigm of self-organized criticality [B4] is based on the hypothesis that the dynamical systems have a tendency to develop asymptotically to critical states. It is however not at all clear whether these models can be derived from basic physics. It has been also argued [B32] that the criticality is somehow built into the structure of these models so that there actually exists a critical parameter and the dynamics is constructed in such a way as to preserve the value of the critical parameter.

Topological Geometrodynamics (TGD) suggests quite different explanation of $1/f$ noise. The entire Universe predicted by TGD is quantum critical system in the sense that the vacuum functional of the theory is completely analogous to the partition function of a thermal system. The so called Kähler coupling strength α_K is analogous to temperature and the requirement that it corresponds to critical temperature fixes the theory uniquely. Since the critical parameter is fundamental constant of Nature, it is clearly not possible to generate perturbations leading away from criticality without Godly intervention and the basic argument against criticality as an explanation of $1/f$ noise can be circumvented.

Like its thermodynamical counterpart, quantum criticality implies long range quantum correlations. This in turn implies that macroscopic quantum systems of arbitrarily large size are possible. This result is a cornerstone for the TGD inspired theory of bio-systems as macroscopic quantum systems: what remains is to identify the mechanisms making bio-systems macroscopic quantum systems. TGD indeed predicts several, purely TGD based, mechanisms. Needless to emphasize, if quantum criticality could provide a general mechanism explaining the universality of the $1/f$ noise, one would have strong support not only for quantum criticality (and TGD!) but also for the possibility of macroscopic quantum systems. Therefore the hypothesis deserves a serious study.

9.6.2 Quantum Criticality Of TGD

Quantum criticality and p-adicity

As already explained quantum criticality emerges in TGD from the requirement that the theory is unique: as a consequence the value of the Kähler coupling strength, which is analogous to critical temperature, is fixed. The situation is actually somewhat more delicate. The considerations related to the value of gravitational constant lead to the hypothesis that WCW decomposes into regions characterized by p-adic prime p such that the critical value of Kähler coupling strength depends on p and hence on p-adic length scale $L(p)$ in the manner characteristic for the length scale evolution of $U(1)$ coupling strength.

The requirement that gravitational constant is invariant under the coupling constant evolution associated with p-adic prime p plus the requirement that electron mass scale is predicted correctly by p-adic mass calculations [K56], fix the evolution of the Kähler coupling strength as a function of the p-adic length scale:

$$\begin{aligned} \frac{1}{\alpha_K(p)} &= k\left[log(p)+log(K^2)\right] \quad , \\ K &= \frac{R}{\sqrt{G}} \simeq 1.367\times 10^4 \quad . \end{aligned}$$

Here R denotes CP_2 "radius", G denotes gravitational constant and p is the p-adic prime. The value of the parameter k is $k=\frac{4}{\pi}$ in the scenario in which the value of Kähler function is integer for CP_2 type extremals and $k=137/107$ in the scenario allowing the expansion of Kähler function as power series existing p-adically. One can say that instead of single critical value Kähler coupling allows infinite number of critical values labelled by primes and each critical value corresponds to a particular effective p-adic topology.

It seems that a successful p-adicization requires the extension of rational numbers by introducing an infinite group of real units defined by products of ratios $U=(m/n)X/\Pi(m/n)$, where X is product of all finite primes and $\Pi(m/n)$ is an infinite prime. One has $U=1$ in a real sense but not p-adically. This extension is a multiplicative version for the addition of infinitesimals and seems much more better suited for the purposes of physicist. The p-adic norm of these units is $1/p$ for almost all primes and the remaining primes are cognitively very special. If the inverse of the Kähler coupling strength is proportional to this kind of unit the continuation of the Kähler function to p-adic realm becomes easy.

The notion of algebraic hologram suggests itself. This would mean that WCW decomposes into sectors D_Q, Q infinite rational, such that Q defines the subgroup of units for the rational numbers at that point. The value of Q would be reflected in the properties of single point of space-time sheet and would affect decisively the p-adic physics of cognition but would not reflect itself directly at the level of the real physics. At the embedding space level Q would correspond to an octonionic unit. Since octonionic primes could quite well be able to code the quantum state of the entire universe to their structure, one must consider seriously the possibility that single point codes in its structure the quantum state of the universe!

How quantum criticality is realized?

It is not completely clear how criticality is precisely realized in quantum TGD. In fact, criticality seems to be realized in several senses. The most general action containing no dimensional coupling constants is super position of Yang-Mills action for induced CP_2 spinor connection and of Kähler action. This action allows all 4-surfaces with one-dimensional CP_2 projection as vacuum extremals. When the Yang-Mills part of the action vanishes (Yang-Mills coupling becomes formally infinite) action has the huge vacuum degeneracy of Kähler action: any 4-surface whose CP_2 projection belongs to so called Legendre sub-manifold (generically 2-dimensional) of CP_2, is vacuum extremal. It is not clear whether this criticality could give rise to spin glass analogy irrespective of the value of the Kähler coupling strength.

The value of Kähler coupling strength gives rise to additional criticality. From the fact that Kähler electric/magnetic fields give negative/positive contribution to Kähler action it is clear that vacuum functional favors the formation of Kähler magnetic/electric fields below/above the critical value. Therefore configurations containing Kähler magnetic fields, in particular so called cosmic strings, should be favored below criticality. CP_2 type extremals [K56] with negative and finite Kähler action representing elementary particles and surfaces representable as deformations of vacuum extremals and containing Kähler electric fields should be more favored above criticality.

One possibility is that some kind of spontaneous Kähler magnetization occurs below criticality and that in criticality spin glass type structure consisting of regions containing Kähler magnetic fields is present whereas above criticality magnetization is absent. An attractive working hypothesis, motivated by the experience with critical systems, is that at criticality the formation of join along boundaries/flux tube condensates with arbitrarily large sizes is possible: depending on whether the flux tubes contain Kähler electric or magnetic gauge fluxes, single stable join along boundaries/flux tube condensate would be formed above/below criticality. This would mean that the topology of the many-sheeted space-time is extremely dynamical at criticality. This indeed would be necessary for the formation of macroscopic quantum systems of all possible sizes. Examples of join along boundaries bonds are color flux tubes between quarks, strong bonds between nucleons inside atomic nuclei, chemical bonds, MAPs between micro-tubuli and gap junctions between cells.

Information theoretic interpretation of Kähler function

The discovery that Kähler function has information theoretic interpretation led to a considerable progress in the understanding of quantum criticality. The work of Roy Frieden [B30, B31] suggest that the action principles of physics could have information theoretic interpretation. Although Frieden's original scenario does not seem to work in TGD framework, it turns out possible to deduce interpretation for the negative of the Kähler function as an entropy type measure for the cognitive information content of the space-time surface. Furthermore, the criticality of the Kähler action can be interpreted as a maximization of the cognitive information content of the space-time surface and quantum criticality makes TGD universe maximally interesting and maximizes its intelligence.

A detailed argument leading to these results goes as follows. The $I - J$ decomposition of the Kähler function in the manner suggested by Frieden's theory is not General Coordinate Invariant and therefore not promising in TGD context. On the other hand, the formal similarity of the vacuum functional with thermodynamical partition function suggests the interpretation of the vacuum functional as an exponent for the negative of some kind of entropy type variable so that the negative of the Kähler function would correspond to entropy.

The exponent $exp(-K_{cr})$ of the negative of Kähler function, for a suitable choice of the value α_{cr} of the Kähler coupling strength, should somehow measure the number of some kind of microstates. A natural identification of the "microstates" is as cognitive degeneracy caused by the classical nondeterminism of the Kähler action, which implies that WCW integration over 3-surfaces Y^3 at the light cone boundary involves summation over all possible association sequences going through the same 3-surface Y^3 on the light cone boundary and having the same value of the Kähler function. This summation brings in a degeneracy factor, which will be referred to as N_d.

An educated guess is that the degeneracy factor N_d is in a good approximation proportional to the exponent of the negative of the Kähler function, when Kähler coupling strength has critical value α_{cr}:

$$N_d \simeq exp(-K_{cr}) \ . \tag{9.6.1}$$

Note that α_{cr} depends on the sector D_p of the WCW since Kähler coupling strength depends on p-adic length scale in a logarithmic manner typically predicted by $U(1)$ gauge theories. This hypothesis allows to answer to the basic questions related to the definition of the Kähler function.

The first consequence of the hypothesis is that preferred extremal property maximizes cognitive information. This is achieved by generation of Kähler electric fields necessarily accompanied by mind like space-time sheets, whose contribution to N_d compensates the negative Kähler action. Perhaps this could partially explain why electric fields, in particular those associated with the cell membranes, are so important in bio-systems. The construction of cognitive systems artificially some day would thus involve construction of Kähler electric fields.

This hypothesis throws also new light to the precise mechanism of the quantum criticality. At quantum criticality the cognitive degeneracy factor N_d in the functional integral over WCW compensates the exponent of the negative Kähler function even when its value is infinite! Below quantum criticality the probabilities for 3-surfaces having negative Kähler function suffer exponential cutoff so that only the 3-surfaces for which the value of Kähler function per volume vanishes, are important. The resulting universe is obviously much less interesting than quantum critical universe, which maximizes complexity. Also the maximum for the total cognitive information content of the quantum jump is always finite for subcritical universe unlike for quantum critical universe. Above quantum criticality cognitive degeneracy dominates over vacuum functional and configuration space integral of the vacuum functional diverges so that the theory becomes mathematically ill defined. Therefore quantum critical universe possesses maximal complexity and is as interesting and intelligent as universe can be! Note that quantum criticality was already earlier realized to be crucial for consciousness since it makes possible long range quantum correlations and hence arbitrarily large macroscopic quantum systems.

Quantum criticality and $1/f$ noise

Criticality and fractality in quantum TGD are closely related to the properties of the Kähler function defining the Kähler geometry of the WCW of all possible 3-surfaces in $H = M^4_+ \times CP_2$. Kähler function is defined as Kähler action for a preferred extremal of Kähler action. Kähler action allows huge number of vacuum extremals with finite size in both spatial and temporal degrees of freedom. These surfaces are not absolute minima of the Kähler action but one can consider the possibility that by gluing vacuum surfaces to non-vacuum surfaces the interaction with the non-vacuum surfaces makes them almost-vacuum extremals and as a consequence one obtains absolute minimum of Kähler action. Quantum criticality of the material system suggests that this weak interaction could generate large fluctuations with long time and length scales.

A natural hypothesis is that $1/f$ noise results when the space-time sheet containing the physical system is glued to a vacuum extremal. When almost vacuum extremal is created, some energy flows from the physical system to the vacuum extremal. On the other hand, when almost vacuum extremal disappears, this energy flows back to the space-time sheet of the physical system. This mechanism perturbs the physical system and causes a fluctuation. By quantum criticality even small energy flow can give rise to a large perturbation of the physical system. Spin glass analogy which is closely related to the vacuum degeneracy of the Kähler action, predicts that there indeed exist very many almost degenerate maxima of Kähler function and small perturbations could induce time development transforming the 3-surface to a new one. The transition would be analogous to a rapid classical time development leading from one sheet of a cusp catastrophe to another one.

Photons and gravitons (possibly virtual) are the most natural candidates for particles transferred to the non-vacuum space-time sheet. Uncertainty Principle suggests that the energy transferred by single quantum from a material space-time sheet to the almost vacuum space-time sheet of duration T is of order $E \simeq 1/T$. One can consider also a possibility that large number of quanta with energy $E \simeq 1/T$ is transferred to the non-vacuum space-time sheets. TGD predicts the presence of Bose-Einstein condensates of photons and gravitons generated by vacuum currents [K70] and a definite possibility is that a fraction of the topologically condensed coherent photons with energy $E \simeq 1/T$ are Bose-Einstein condensed at the almost non-vacuum space-time sheet. In this case only the amount of energy transferred would be larger and the changes to cause long length scale fluctuation of large amplitude and having frequency $\omega = E$ at the non-vacuum space-time sheet containing matter, would be better.

If one requires scaling invariance in the strongest possible sense, the only viable probability distribution for the durations of the almost vacuum space-time sheets is $dP(T) \propto dT/T$ since any other distribution law would necessarily contain some dimensional parameter. By Uncertainty Principle the same distribution gives also the distribution of energies: $dP(E) \propto dE/E$. Obviously the proposed distribution implies duality between energy and time variables and is especially natural from the view point of quantum theory. Actually the spectrum is of the same form as brehmstrahlung spectrum and one can consider the possibility that the space-time sheets of finite time duration could be regarded many particle states formed by real and virtual collinear photons and gravitons.

Quite generally, one can identify energy E as the frequency ω of the fluctuation generated by the transfer of energy. Quantum criticality suggests that the energy transferred to the non-vacuum space-time sheet serves only as a seed of a fluctuation whose average amplitude squared approaches constant at the limit $E = \hbar\omega = hf \rightarrow 0$. The non-vanishing of the constant in question follows from quantum criticality implying the presence of fluctuations at arbitrarily long time scales. With these assumptions one indeed obtains $1/f$ power distribution for the frequencies

$$S(f) \propto \frac{df}{f} \quad . \tag{9.6.2}$$

9.6.3 $1/F$ Noise And Thermalized Arithmetic Quantum Field Theory

Following arguments demonstrate that $1/f$ noise follows automatically from either p-adic or real thermodynamics applied to arithmetic quantum field theory with energies quantized as multiples of $log(p)$, p prime. There are small corrections to $1/f$ spectrum and these reflect directly the distribution of primes. Obviously this serves as a high precision test for the proposed explanation of $1/f$ noise.

Arithmetic quantum field theory with broken conformal symmetry describes critical systems

Two-dimensional critical systems allow description in terms of conformal quantum field theories [A22]. On the other hand, quantum TGD relies crucially on the realization of super conformal invariance made possible by the miraculous properties of the boundary of the four-dimensional future light cone [K30]. This background inspires the hypothesis that critical systems quite generally possess some form of conformal invariance possibly broken to some sub-algebra.

The generators of the full number-theoretic conformal symmetries are

$$L_q = q^z \frac{d}{dz} \quad , \tag{9.6.3}$$

where q is rational number. Commutators satisfy the commutation law

$$[L_{q_1}, L_{q_2}] = log(\frac{q_2}{q_1}) L_{q_1 q_2} \tag{9.6.4}$$

respecting multiplication of rationals.

Generators are eigen states of $L_1 = d/dz$ under commutation. L_1 is analogous to energy (or momentum) since it generates translations. Energy eigenvalues are

$$E = E_0 log(q) = E_0 \sum_{k_i \in Z} k_i log(p_i) \quad , \tag{9.6.5}$$

where p_i are primes and k_i are integers which can be also negative. If physical states correspond to integers for which energy is always positive, one has

$$E = E_0 \sum_{k_i \geq 0} k_i log(p_i) \quad , \tag{9.6.6}$$

which is the energy spectrum of arithmetic quantum field theory, which describes the physics of infinite number of harmonic oscillators labelled by primes and having fundamental frequencies $f_p = log(p)f_0$ ($E_0 = hf_0$). The positivity of the spectrum suggests that the interpretation as energy rather than momentum is indeed more appropriate.

The generators L_p and $L_{1/p}$ generate the entire algebra by repeated commutations. What is remarkable, is that one obtains infinite hierarchy of symmetry breakings by dropping any subset of generators labelled by some subset of primes. An interesting hypothesis is that arithmetic quantum field theory with symmetry broken in this manner describes some critical systems. Analogous hierarchy of symmetry breakings is possible also for ordinary Super Virasoro algebra.

If one assumes $p \simeq 2^k$, k prime, one obtains special kind of breaking of conformal symmetry. In this case the scaled generators

$$\hat{L}_k \equiv \frac{L_{p\simeq 2^k}}{log(2)} \tag{9.6.7}$$

have energies $\hat{L_1} \simeq k$. The algebra commutators satisfy commutation relations

$$[L_{n_1}, L_{n_2}] \simeq (n_2 - n_1)L_{n_1+n_2} \ , \tag{9.6.8}$$

so that one has in a good approximation standard conformal algebra of string models and statistical models of critical systems [A22]. This observation suggests a symmetry-based justification for p-adic length scale hypothesis besides the justification coming from the generalization of Bekenstein-Hawking law for black-hole entropy to elementary particle context [K56].

Thermodynamics for arithmetic quantum field theory

$1/f$ spectrum follows in a straightforward manner by applying p-adic or ordinary thermodynamics to arithmetic quantum field theory.

1. The spectrum of frequencies in a mode p is harmonic oscillator spectrum:

$$f_n = nf_0 \times log(p) \ , \tag{9.6.9}$$

   where n is integer identifiable as number of arithmetic bosons. f_0 is infrared cutoff for frequencies.

2. The average number of particles in the mode p is calculable form p-adic thermodynamics. In p-adic thermodynamics Boltzmann weight $exp(-\beta H)$, $\beta = 1/T$ (the units are $\hbar = c = k = 1$ in the following), does not exist as such p-adically and one must replace it by power of p which exists under certain constraints on the energy spectrum satisfied in conformally invariant theory:

$$exp(-\beta H) \rightarrow p^{\beta H} \ . \tag{9.6.10}$$

   For number-theoretic reasons one must assume that

$$H \equiv \frac{L_1}{log(p)} \tag{9.6.11}$$

   having integer valued spectrum is in the role of Hamiltonian H. This operator has eigenvalues $p^{\beta n}$. Inverse temperature β must be positive-integer valued from the requirement that Boltzmann weights exist p-adically:

$$\beta = m \ . \tag{9.6.12}$$

3. The partition function for mode p is nothing but standard harmonic oscillator partition function

$$Z = 1 + p^m + p^{2m} + ... = \frac{1}{1-p^m} \quad . \tag{9.6.13}$$

The average value of particle number in mode p is given by

$$\langle n \rangle = \frac{\sum_n np^{nm}}{Z} = \frac{p^m}{1-p^m} \quad . \tag{9.6.14}$$

The real counterpart of average particle number is obtained using canonical identification

$$\sum x_n p^n \rightarrow \sum_n x_n p^{-n} \tag{9.6.15}$$

mapping p-adic observables to real ones and one obtains

$$\langle n \rangle_R = \frac{p^{-m}}{1-p^{-m}} \quad . \tag{9.6.16}$$

For large primes one obtains in excellent approximation $\langle n \rangle_R \simeq p^{-m}$.

4. This construction applies with minor modification also in real context. In this case one has

$$\langle n \rangle = \frac{\sum_n np^{-\beta n}}{Z} \quad , \quad Z = \sum_n p^{-\beta n} \quad , \tag{9.6.17}$$

where one has $\beta = f_0/T$. The resuting expression is the same as given by p-adic thermodynamics except that β is now real-valued:

$$\langle n \rangle = \frac{p^{-\beta}}{1-p^{-\beta}} \quad . \tag{9.6.18}$$

$1/f$ noise from thermal arithmetic quantum field theory

To deduce $1/f$ spectrum it is enough to calculate the average number of states $N(f)$ with frequency smaller than f using the approximate expresssion

$$\pi(x) \simeq \frac{1}{u} \quad , \quad u = log(x) \tag{9.6.19}$$

for the density of primes in the set of reals x [A13]. Thus, in the approximation $\langle n \rangle = p^{-\beta}$, one has

$$\begin{aligned} N(f) &= \sum_p \frac{p^{-\beta}}{1-p^{-\beta}} \simeq \int dx \frac{x^{-\beta}}{1-x^{-\beta}} \times \frac{1}{u} \\ &= \int_{log(2)}^{log(p)} du \times \frac{exp[(1-\beta)u]}{1-exp(-\beta u)} \times \frac{1}{u} \quad . \end{aligned} \tag{9.6.20}$$

From this one has

$$\frac{dN}{df} = \frac{exp\left[(1-\beta)\frac{f}{f_0}\right]}{\left[1-exp(-\beta\frac{f}{f_0})\right]} \times \frac{1}{f} \quad . \tag{9.6.21}$$

Approximate $1/f$ spectrum is obtained in the frequency range

$$\frac{1}{\beta} \ll \frac{f}{f_0} \ll \frac{1}{|\beta - 1|} \quad . \tag{9.6.22}$$

Clearly, $\beta \geq 1/2$ is required meaning that temperature is below $T = 2f_0$. For $\beta = 1$ $1/f$ spectrum becomes exact at sufficiently high frequencies and its normalization is fixed completely. It is important to notice that for reasonable cutoff frequencies, say of order $f_0 = 10$ Hz, the value of the temperature must be extremely low: or order $T \sim 10^{-10}$ Kelvin. Therefore new physics is necessarily involved.

$T \to \infty$ limit exist only in real context and gives

$$\frac{dN}{df} = \frac{f_0 exp(\frac{f}{f_0})}{\beta f^2} \quad . \tag{9.6.23}$$

Long range temporal correlations clearly disappear at this limit.

It is interesting to look how the situation changes when the allowed primes satisfy the constraint given by p-adic length scale hypothesis. The first observation is that for suitable unit of frequency frequencies are in good approximation prime-valued in this case, which is unique signature of the spectrum. The spectrum is given by

$$N(f) = \sum_{p \simeq 2^k} \frac{p^{-\beta}}{1-p^{-\beta}} \simeq \int dx \frac{2^{-x\beta}}{1-2^{-x\beta}} \times \frac{1}{log(x)} \quad . \tag{9.6.24}$$

$$\frac{dN}{df} = \frac{1}{f_0 log(\frac{f}{f_0})} \times \frac{2^{-\beta\frac{f}{f_0}}}{\left[1-2^{-\beta\frac{f}{f_0}}\right]} \quad . \tag{9.6.25}$$

Exponentially decaying spectrum is obtained for higher frequencies for finite values of the temperature reflecting very strong long range temporal correlations. For high temperatures the spectrum becomes

$$\frac{dN}{df} \simeq \frac{1}{log(2)\beta} \times \frac{1}{log(\frac{f}{f_0})f} \quad , \tag{9.6.26}$$

and differs from $1/f$ spectrum obtained in general case by different normalization factor and by logarithmic correction term. Thus the deviation of the normalization factor from unity could be interpreted as signature of the breaking of conformal symmetry implied by p-adic length scale hypothesis and the value of the temperature can be determined from cutoff frequency and normalization factor of $1/f$ spectrum. Note that in this case $1/f$ spectrum results for cutoff frequencies f_0 much smaller than room temperature, which corresponds to frequency of order 10^{13} Hz.

To sum up, thermalized arithmetic QFT implies $1/f$ spectrum and deviations from the precise $1/f$ spectrum reflect the properties of the distribution of primes since the dominating frequencies in the spectrum are essentially logarithms of primes in general case and primes in case that p-adic length scale hypothesis holds true. In p-adic thermodynamics $T/f_0 = 1/m$ are the only allowed temperatures and $T/f_0 = 1$ corresponds to the highest possible p-adic temperature: note that the calculation of the elementary particle masses using p-adic thermodynamics assumes also $T = 1$ [K56]. In its recent form TGD cannot predict the allowed values of f_0. Certainly transmutation of the fundamental p-adic length scale of order 10^4 Planck length is involved making possible small-p p-adicity at macroscopic length and time scales.

A possible connection between arithmetic quantum field theory, hydrodynamic turbulence, and chaos in excitable media

Turbulence in atmospheric hydrodynamics (flow is associated with a thin boundary layer of about 10 km) has fractal structure and is accompanied $1/f$ noise [K2]: both features associated with self-organized criticality and deterministic chaos. The mechanism giving rise to macroscopic coherent structures such like hurricanes and tornadoes has remained poorly understood in the framework of ordinary hydrodynamics [I38]. Typical structures involved are spiral vortices [I38]

$$\frac{r}{r_0} = \tau^{\frac{\theta}{\theta_0}} \quad , \quad \tau = \frac{1+\sqrt{5}}{2} \quad , \tag{9.6.27}$$

having the property that for large values of n the values of radii at $\theta_n = n\theta_0$ are proportional to Fibonacci numbers $F_n \simeq \tau^n$ (τ denotes Golden Mean). The favored value of θ_0 corresponds to $\theta_0 = 36$ degrees giving rise to Fibonacci spirals encountered widely in botany and associated with aperiodic Penrose tilings with five-fold rotation symmetry [A31].

In TGD hydrodynamic vortices are accompanied by Z^0 magnetic fields whose flux tubes are parallel to the spiral vortex cores. At the tip of the vortex the conserved Z^0 magnetic flux must go somewhere. The only possibility seems to be that it flows to another space-time sheet. This suggests that spiral vortices are associated with what I have called wormhole magnetic fields [K121]. These are double-sheeted structures carrying opposite magnetic fields created by rotating extremely tiny elementary particle sized wormhole contacts at the boundaries of second sheet of the double sheeted structure and feeding electric gauge fluxes between the two space-time sheets. If second sheet has negative time orientation, its energy is negative, and the structure can have finite time duration and be created spontaneously without any energy cost. Thus mind like space-time sheet is in question by definition. This in accordance with the idea that $1/f$ noise involves mind like space-time sheets in essential manner. Wormhole magnetic fields form a fractal hierarchy since space-time sheets can be glued to space-time sheets and this hierarchy can be identified as a fractal hierarchy of vortices containing smaller vortices inside them.

This picture inspires the following hypothesis: it is the excitations associated with wormhole magnetic fields, which are described by arithmetic quantum field theory. The mode with energy $log(p)$ corresponds to a definite structure, perhaps smaller space-time sheet carrying magnetic field glued to the larger sheet. These structures are labelled by primes and thus the distribution of primes is reflected in the dynamics of the system. Wormhole magnetic fields might provide general description of the spiral waves associated with various excitable systems. In particular, generation of chaos by the decay of spiral waves [A3] could correspond to the development of magnetic chaos. Since the phase increment of the order parameter of super-conductor over a closed circuit surrounding magnetic flux tube gives essentially magnetic flux [K51], magnetic chaos implies chaos for the phase of the order parameter of super conductor. Thus magnetic or Z^0 magnetic chaos at cellular level could spoil coherence of the macroscopic quantum phases crucial for bio-control in TGD inspired model of bio-control. For instance, this loss of quantum coherence could lead to heart failure known to involve the decay of spiral waves [A4, A17].

Connection with TGD inspired theory of conscious systems

For f_0 or order say 10 Hz, the temperature associated with $1/f$ noise is extremely low, something like 10^{-10} Kelvin. Standard physics does not certainly allow earthly systems with so low temperatures. In TGD Universe situation is different because the space-time is many-sheeted. In fact, TGD based theory of brain as a macroscopic quantum system relies crucially on the existence of cellular space-time sheets having ultra-low temperatures and allowing the presence of various types of Bose-Einstein condensates. It his view is correct, $1/f$ noise could be seen as a direct signature of consciousness. A natural TGD inspired interpretation for the arithmetic QFT could be as a statistical description of the dynamics at the mind like space-time sheets having by definition finite time duration $\tau = 1/f_0$. mind like space-time sheets are indeed suggested to give rise to $1/f$ noise which thus would become direct signature of consciousness [K23]. Around human brain τ could be even of the order of lifetime: mind like space-time sheets with this duration make possible long term episodal memories in the proposed general theory of qualia [K41]. Thus the standard formal trick of performing path integral over space-time of finite time duration to construct thermodynamical quantities [B29] seems to have deeper "psycho-physical" meaning in TGD framework.

In TGD inspired theory of bio-systems as macroscopic quantum systems so called association sequences [K58] provide geometric representation for thoughts and in fact are almost vacuum space-time surfaces with a possibly finite duration. Therefore one can consider seriously the possibility that $1/f$ noise is closely related to the basic mechanism with which brain and living matter control the behavior of the matter.

More concretely, "massless extremals" (MEs) are basic solutions of field equations of TGD and define an excellent candidate for an infinite hierarchy of life forms having huge information storage capacities and expected to control lower level selves such as super-conducting magnetic flux tube structures. MEs are accompanied by non-vanishing light like vacuum gauge currents generating coherent states of gravitons and photons [K70]. Linear structures such as micro-tubuli and DNA molecules are excellent candidates for quantum antennae generating coherent light and perhaps also gravitons. In fact, infinite fractal hierarchy of MEs extending from elementary particle length scales to cosmological length scales is predicted.

That also gravitons might be important is suggested by the fact that it is the classical gravitational field (induced metric) which destroys the exact $U(1)$ gauge invariance (gauge transformations being represented by canonical transformations of CP_2) of the ordinary Maxwell action when the ordinary Maxwell field is replaced with the induced CP_2 Kähler form [K16]. This gives rise to spin glass type degeneracy due to the huge number of almost physically equivalent gauge-related 4-surfaces. Also the fact that the super-symplectic representations associated with MEs are genuinely quantum gravitational states supports this view.

To sum up, this picture suggest that $1/f$ fluctuations could be even regarded as a physical signature for the presence life and cognitive consciousness: if this is true then the universality of $1/f$ noise could mean that even cognitive consciousness is everywhere.

9.7 The Role Of ELFFields In Bio-Control AndCoordination

In this section the evidence that higher levels of the biological self hierarchy control biological body using fields at ELF frequencies (EEG frequencies are in ELF range) is discussed. The basic inputs are topological field quantization, the idea of memetic code and the observations about the effects of ELF em fields to brain suggesting that the higher levels of our self hierarchy correspond to em selves with sizes of order wavelength of photons generated by EEG currents and thus realized as topological field quanta having size of order of Earth.

A very important and rather recent input (I am writing this towards the end of year 2005) is the model of high T_c superconductivity inspired by the notions of dark matter hierarchy based on the dynamic and quantized $\hbar$ having arbitrarily large values. Detailed models are not discussed here but are left to the chapters [K21, K22] of [K76] devoted to superconductivity in bio-systems.

9.7.1 Electromagnetic Selves

Rather remarkably, the time scale of.1 seconds predicted by the model of the memetic code and also the time scales of the photons associated with the cyclotron frequencies of ions correspond to the time scale of EEG. The currents generating EEG certainly create weak electromagnetic radiation fields which in TGD framework correspond to topological field quanta of size of Earth. The lowest Schumann frequency is roughly $f = c/2\pi R$, R radius of Earth, and equal to $f \simeq 7.8$ Hz. It is known that EEG frequencies are in the same frequency range as so called Schumann frequencies 7.8, 14, 20, 28, 33, 39, ... Hz [F7] associated with the resonances of the electromagnetic fields in the 80 km thick wave cavity between Earth surface and ionosphere. The higher EEG frequencies seem to correlate with higher Schumann resonance frequencies: in particular, the frequencies 13 and 39 Hz which are also cyclotron resonance frequencies of Na_+, are very near to Schumann frequencies. Schumann frequencies vary in time and it has been found that also the variations of EEG frequencies correlate with this variation. Magnetic perturbations near Schumann frequencies are known to have profound effects on human brain inducing altered states of consciousness and cortical instabilities such micro-seizures and epilepsies [J57, J66].

The photons generated in cyclotron transition associated with macroscopic ionic BE condensates in Earth's magnetic field have wavelengths of order Earth size and the topological field quanta representing classically the radiation field have size of Earth. A possible mechanism generating EEG waves would be the dropping of ions or their Cooper pairs from smaller space-time sheets to high n cyclotron states at the magnetic flux tubes of Earth and the decay of the cyclotron states via emission of radiation at harmonics of cyclotron frequency.

In many-sheeted space-time particles (see **Fig.** `http://tgdtheory.fi/appfigures/manysheeted.jpg` or **Fig.** 9 in the appendix of this book) topologically condense at all space-time sheets having projection to given region of space-time so that this option makes sense only near the boundaries of space-time sheet of a given system. Also p-adic phase transition increasing the size of the space-time sheet could take place and the liberated energy would correspond to the reduction of zero point kinetic energy. In this case the process would occur coherently for all particles. Particles could be transferred from a portion of magnetic flux tube portion to another one with different value of magnetic field and possibly also of Planck constant h_{eff} so that cyclotron energy would be liberated.

EEG could be also generated as coherent photons generated by Josephson current varying at ELF frequency [K22]. Dark matter hierarchy indeed predicts a hierarchy of Josephson junctions and that ELF photons at sufficiently high level of dark matter hierarchy correspond to photon energies above thermal threshold. This model leads also to a new view about genetic code and to a model how cell membrane and nucleus co-operate to achieve bio-control. It is quite possible that both mechanisms are involved. In fact, Josephson radiation model generalizes so that Josephson energy is dominated by the difference of cyclotron energies of ion at flux tube portions at different sides of cell membrane [K80].

The fact that classical ELF em fields are represented by topological field quanta with size of order Earth size (by Uncertainty Principle alone) raises the question whether our "physical" body is only a tip of an iceberg and formed by the topological condensation of the bio-matter around electromagnetic topological field quanta serving as templates for the bio-structures.

These observations and arguments suggest the identification of the relevant selves in our self-hierarchy are electromagnetic selves having the size of Earth and correspond to EEG frequencies, and raises the idea that our magnetic body (or hierarchy of magnetic bodies) corresponds to "me" as intentional agent, and that also the magnetic bodies of other systems, in particular Earth itself, are conscious entities and intentional agents. Dark matter hierarchy discussed in [K21, K22] gives a precise quantitative content to this vision.

9.7.2 Neuro-Psychological Evidence For The Importance Of ElfFields

There is quite a lot of neuro-psychological evidence for the importance of ELF fields.

The work of Michael Persinger

Neuroscientist Michael Persinger [J58, J56, J72] from Laurentian University in Canada believes that temporal lobes are electrically unstable and may also be involved in sensing these fluctuations in the Earth's magnetic field. In-stability results in micro-seizures in sensitive individuals [1]. Persinger proposes that his tectonic strain theory [J58, J72] explains UFO experiences as natural phenomena generated by stresses and strains within Earth's crust. The anomalous luminous phenomena, UFO experiences and earthquake would be caused by the same process: earth stress causing local strains and eventually leading to sudden release of seismic energy. These phenomena are also reflected in geomagnetic field and most notable perturbation occurs at electromagnetic resonance frequency of 8 Hz of Earth for the propagation of electromagnetic fields in the spherical cavity below ionosphere This resonant frequency interacts with human brain and generates what would have been interpreted as spirit in Indian culture and is interpreted as UFO in our culture.

Altered states of consciousness can be also induced using patterns of magnetic fields with basic frequency of 8 Hz and Persinger suggests that these patterns could have something to do with the "fundamental algorithms" of brain [J56]. One example of the induced experiences is the experience about presence of something. If left brain half is stimulated, this something is experienced as friendly, when right half is stimulated it is experience as scary. Women experience

[1] On basis of my personal experiences I have reasons to believe that I belong to those sensitive individuals

this something as a man and vice versa. Persinger claims that also mystic and religious experiences can be induced using magnetic fields [J56]. The frequency range producing the claimed effects is around 10 Hz with accuracy of 1 Hz. Persinger has gone so far as to design a magnetic helmet that pulses the temporal lobes with earth resonance frequencies producing mystical experiences in student volunteers.

What is remarkable that Persinger uses magnetic pulses rather than smooth sine waves. This encourages to think that magnetic pulses induce scalar wave pulses, which accelerate charges particles at the space-time sheets of scalar wave pulses and generate negative energy "acceleration radiation" in turn inducing time mirror mechanism (see **Fig.** `http://tgdtheory.fi/appfigures/timemirror.jpg` or **Fig. ??** in the appendix of this book) at the harmonics of frequency defined by the duration of the scalar wave pulse presumably equal to the rising time of the pulse.

It should be emphasized that Persinger is hard nosed neuro scientist and materialist and uses his findings as a support for the reduction of religious experiences to neuronal level and to geophysical phenomena. Persinger also claims that surprisingly many religious people have suffered some brain injury during some state of their life. Persinger bases his explanation of religious experiences to the instability of the frontal lobes against micro-seizures (invisible epilepsies) induced by the magnetic perturbations with certain resonance frequencies, which happens to be resonant frequency of the perturbations of Earth's magnetic field.

Even forgetting Persinger's materialistic starting assumptions, one can criticize Persinger's conclusions in several respects. Why brain would have developed this kind of instability if it produces only hallucinations? Why just the resonance frequency of Earth's magetic field? The content of these hallucinations is the experience about the existence of some higher level consciousness. On the other hand, these hallucinations are produced by interaction with Earth: could this be an accident?

Consider now the situation in which an oscillatory magnetic field varying with certain frequency is generated by Earth quake or artificially.

1. The interaction of brain with the nearby magnetic field must reduce to the interaction of magnetic flux tubes with some parts of brain. It is known that this interaction can lead to electric in-stability of frontal lobe leading to micro-seizures.

2. The coupling of the frontal lobes with Earth's magnetic field can be understood if the flux tubes of the magnetic and Z^0 magnetic fields of Earth serve as templates for the formation of bio-structures. This implies that the biological network of the magnetic flux tubes associated with axons is part of the much larger flux tube network characterizing Earth's magnetic field. The order of magnitude estimate for the thickness d of the magnetic flux tubes associated with Earth's magnetic field is obtained by assuming quantization of magnetization flux. This $d \sim \sqrt{2/eB}$ giving $d \sim 4\times 10^{-6}$ meters for $B \sim .5\times 10^{-4}$ Tesla. The diameter of flux tube is very near to the p-adic length scale L_p, $p \simeq 2^k$, $k = 169$: $L(169) \simeq 4.4\times 10^{-4}$ meters. This length scale is the p-adic length scale associated with cells. Indeed, the quantitative TGD based models for nerve pulse and EEG, for cognition, and for the quantum correlates of sensory qualia, rely crucially on the magnetic transition frequencies of various super conducting charged particles in Earth's magnetic field.

3. The mechanism generating altered states of consciousness could be following. The perturbations of Earth's magnetic field with resonance frequencies cause oscillatory perturbations of the magnetic flux tubes. The interaction of these perturbations with the two-layered structures of brain glued to magnetic flux tubes makes possible resonant coupling with the "Indra's net" formed by the magnetic flux tubes and massless extremals describing the classical em field of Earth.

   More concretely, the resonant oscillations of Earth's magnetic field "wake-up" some higher level sub-selves (mental images) in the self-hierarchy of a sensitive person so that the higher level component to our experiences becomes exceptionally intensive. The mechanism wake-up is resonance: some Schumann frequencies are very near to the magnetic transition frequencies of ions crucial for the function of brain. Indeed, both K_+ (7.5 Hz) and Cl_- (8.5 Hz) cyclotron frequencies are very near to the lowest Schumann frequency of about 7.8 Hz and $n = 1$ and $n = 3$ multiples Na_+ cyclotron frequency (13 Hz) are also very near to Schumann frequencies.

4. One can wonder why the coupling (possibly entanglement) with the higher level selves is not permanent, why strong oscillatory perturbations are required to achieve this. Perhaps this has to do with the dimensions. Two 4-surfaces in 8-dimensional space (now "Indra's web" and 4-surface associated with cell layers) have generically discrete set of stable intersection points. These must give rise to topological sum contacts giving rise to interaction of material space-time sheets with classical radiation fields. For magnetic flux tubes which are perturbed so that they oscillate with large amplitude one can expect that the number of intersections with the 4-surface describing cell layers, is proportional to the frequency of oscillation and to the amplitude of oscillation. Note that this picture realizes Feynman diagrammatics topologically and that the realization is possible only in dimension 8 since in higher dimensions two 4-surfaces have no intersections in the generic case.

Dark matter hierarchy with levels characterized by the values $\hbar = \lambda^{k_d}\hbar_0$, $\lambda \simeq 2^{11}$, allows to develop much more concrete ideas about the interaction of human brain with the Earth's magnetic field [K22]. Later a more general hypothesis allowing all powers of 2 emerged and corresponds for the hierarchy of Planck constants the hypothesis $h_{eff} = nh$, where n is product of distinct Fermat primes and power 2^{k_d}. In this model $k_d = 4$ level of the dark matter hierarchy corresponds to the space-time sheets of Earth's magnetic field to which brain is connected by magnetic flux sheets traversing through DNA. $k_d = 4$ flux sheets act as Josephson junctions of thickness ~ 180 km connecting the region of Earth below litosphere to the magnetic flux quanta of Earth's magnetic field above ionosphere. In this picture organisms in biosphere can be seen as scaled up variants of proteins in the cell membrane acting also as Josephson junctions. The highly folded magnetic flux sheets mediate the perturbations of the flux quanta of Earth's magnetic field to brain and explain the strong effects of Schuman resonances and perturbations of Earth's magnetic field on consciousness.

Other evidence

There are also "mind machines" which anyone can buy (see for instance [J55]), which produce meditative states through entrainment of brain waves, using light and sound at ELF frequencies. For instance, by feeding in ears two audible frequencies differing by about 8-10 Hz, it is possible to generate mystic experiences. Also light and sound oscillating with these frequencies can be used to generate altered states of consciousness. Indeed, important cyclotron frequencies are in this range. That the alpha frequency of the brain as determined by electroencephalograph is in the range of 8 to 10 Hertz, may not be a coincidence. Perhaps when yogis and adepts are modulating their brain wave frequencies during meditation, they really are achieving altered states of consciousness by tuning in to the Earth. Resonant coupling would be the classical correlate of strong entanglement.

It has been also observed that magnetic pulses of duration of order millisecond and with frequencies between 1 and 50 Hz have profound effects on brain [J24]. For instance, depression can be cured in some cases by transcranial magnetic simulation (TMS) [J24]. Depression correlated with anomalously low neural activity of some parts of left frontal lobe (anterior cingulate cortex belonging to limbic system). During sadness this region is very active. This would suggest that depression is not about feeling sad but about not being able feeling sad. It might be that too much sadness causes numbness to sadness, depression. A prosaic explanation for the effect of 1 millisecond pulse sequence is that the pulses act like a sequence of kicks to broken household machine. Electro-convulsive therapy (ECT), which also stimulates brain act like a single big kick and causes micro-seizures and convulsions avoided in TMS.

It has been proposed that hauntings could be explained acoustically. On basis of his personal experiences Vic Tandy [J78] has proposed that resonant sound waves at frequency of about 19 Hz can cause experiences like cold chills, sense of paranoia and distress and visual hallucinations. Laboratory research has indeed shown that very low frequency infra sounds can cause unpleasant physiological effects like shivering, anxiety and breathlessness. The resonance frequency of eye is known to be about 18 Hz and this the resulting smearing of vision could explain hallucinations. On the other hand, second harmonic for Schumann resonance is roughly 20 Hz. Of course, one can ask whether there is some deeper reason for why the resonance frequency of eye is near to Schumann resonance and whether this frequency is closely related to some Z^0 magnetic Larmor frequency, which are of order 20 Hz for the "emotional" $k = 173$ space-time sheet carrying Z^0 magnetic field having minimal field strength about $g_Z B_Z = eB/16$ by flux quantization.

More generally, one can also ask why various biorhythms are in Hz [E4] [F7]: one could indeed identify geophysical frequencies which are near to various frequencies of body. One can also aks why the effect of music to human brain is so deep. Could it be that also music wakes up higher level selves in our self-hierarchy? In fact, the quantum model for auditory experience leads to just this conclusion.

9.7.3 Effects Of Elf- And ELFModulated EM Fields On Living Matter

The work by pioneers of of bio-electromagnetism (Wertheimer, Milham, Marino, Becker, Adey, Blackman and others) which began already at sixties led to amazing discoveries about ELF fields on brain. The review article of Blackman provides a detailed summary of these developments [J23].

1. Already at sixties Hamer discovered that ELF em fields in EEG frequency range had effects on the reaction times of human volunteers [J47]. At seventies Bawin and Adey [J14] discovered the effects of ELF em fields on calcium release in brain tissue. Maximum effect on Ca release was found at 16 Hz.

2. Blackman found 1979 that 50 MHz field modulated by 15 Hz ELF field increased Calcium ion release in chick brain tissue [J32]. Blackman also discovered that odd multiples 15, 45, 75, 105... of 15 Hz had much stronger effect on tissue than even multiples 30, 60, 90... Hz and realized the importance of Earth's magnetic field [J33, J34, J35]. The results and speculations of Blackman led Liboff to propose ionic cyclotron resonance model [J12]. This model was classical and subject to grave objections at the level of principle [K22]. Obviously cyclotron and Larmor frequencies in Earth's magnetic field are in the frequency range of EEG.

3. Also the Schumann resonances associated with Earth's em field are in EEG frequency range and it is known that geomagnetic fields interact strongly with brain and Persinger [J58, J56] has done valuable work related to this.

9.7.4 Summary About Effects Of ELFEM Fields On Brain

The work by pioneers of bio-electromagnetism (Wertheimer, Milham, Marino, Becker, Adey, Blackman and many others) which began already at sixties led to amazing discoveries about ELF fields on brain. The article of Blackman [J23] provides a detailed summary of these developments. The results of the work of Bawin, Adey, Blackman and others can be summarized by saying that radio frequency em fields amplitude modulated by ELF frequencies affect in certain frequency and amplitude windows brain tissue [J14, J33, J35]. The function of the radio frequency carrier wave is to facilitate the penetration of em field into tissue and its frequency is not essential for the occurrence of the effect. Presumably nonlinear effects give rise to a secondary wave with modulation frequency which is the primary source of effects.

Basic effects

The effects of ELF em fields on brain include chemical, physiological and behavioral changes within windows in frequency and field intensity. It is essential that the effects have been observed only in vertebrates which thus possess EEG. A good summary is the online review article of Cherry [J60].

The well documented and established non-thermal biological effects of EMR include significant alteration of cellular calcium ion homeostasis, reduction of melatonin, and the detection of Schumann Resonances by human and avian brains. A key effect is change in Ca^{2+} homeostasis: Ca^{2+} it is involved with both pre- and postsynaptic steps of nerve pulse transmission and also with intracellular communication. For instance, Ca^{2+} is involved with gene expression, the development and plasticity of nervous system, modulation of synaptic strengths, and with $Ca^{2+}-c$AMP signal transduction process.

Change in Ca^{2+} homeostasis has harmful effects in central nervous system, endocrine system and immune system. At the level of CNS this means changes of reaction time and behavioral alternations. At the level of neuro-endocrine system a good example is the reduction of the melatonin production in pineal gland having wide variety of harmful effects since melatonin serves as effective scavenger of free radicals: among the effects are DNA strand breakage, chromosome aberrations and problems with gap junction communications. Melatonin is also crucial for healthy sleep and for the reduction of cholesterol and blood pressure. In case of immune system an example is provided by the change of functioning of lymphosytes in turn reducing the competence of immune system making the subject more vulnerable to allergens, toxins and viruses.

Amplitude windows

Two main amplitude windows have been seen. For the first window ELF em fields have values of electric field in tissue around 10^{-7} V/m. The effects are high level effects and associated with navigation and prey detection in marine vertebrates and with the control of human biological rhythms. For ELF modulated radio frequency fields (RF) and microwaves (MW) the intensities are around $1-10$ V/m. In this case the effects are neurophysiological effects are lower level effects at the level of the brain tissue. In case of brain tissue maximal sensitivity to electromagnetic fields occurs between 6 and 20 Hz.

In order to get grasp about orders of magnitude, it is good to notice that cell membrane electric field has a strength about 10^7 V/m whereas EEG electric fields in the range $5-10$ V/m. The fact that the second intensity window corresponds to $1-10$ V/m suggests that the em field simulates the em field associated with EEG: a valuable guideline in attempts to understand what is involved. For Schumann resonances electric field is of order .6 mV/m. For sferics (em perturbations associated with lightnings) magnetic field strength is not above nTesla: this corresponds to electric field strength 10 V/m associated also with EEG waves [J41]. Field strength of V/m corresponds roughly to energy flux $\mu W/m^2$.

The presence of windows and weak intensities implies that the effects cannot be thermal. A good metaphor is the effect of radio noise on radio receiver: it occurs at definite frequency and destroys the information content of the original transmission.

The effects occur at harmonics of cyclotron resonance frequencies

Blackman also discovered that odd multiples 15, 45, 75, 105... of 15 Hz had much stronger effect on tissue than even multiples 30, 60, 90... Hz and realized the role of Earth's magnetic field [J34]. A possible interpretation is that harmonics of cyclotron frequencies might be the information carrying frequencies in EEG.

In response to the results and speculations of Blackman, Liboff formulated ionic cyclotron resonance (ICR) model [J12] based on the realization that the frequencies in question correspond to multiples of the cyclotron frequencies of Ca^{2+} ion in Earth's magnetic field. This model was classical. Later Blanchard and Blackman proposed so called ionic parametric resonance model (IPR) [J20]. This phenomenological model combines ICR model with ideas about atomic physics. There are several objections against ICR model; classical orbits of ions in Earth's magnetic field have radius of order meters; dissipative effects and Brownian forces do not allow cyclotron orbits; charge-to mass ratios appearing in cyclotron frequencies correspond to vacuum rather than water environment characterized by large value of dielectric constant; it is difficult to understand why odd multiples of cyclotron frequencies give rise to stronger effects [J23]. Some of these objections apply also to IPR model.

The pattern of data seems to suggest that the interaction occurs at quantum level. This is in dramatic conflict with the predictions of the standard quantum theory and with the standard view about space-time. On the other hand, the fact that effects at spin flip frequencies proportional have not been reported suggests that the effects are classical. Large $\hbar$ hierarchy however predicts that spin flip energies behave like $1/\hbar$ whereas cyclotron energy do not depend on the value of $\hbar$ so that only cyclotron transitions are predicted to be important.

Are quantal effects in question?

The conclusion that the effect of ELF fields on brain represents quantum effects associated with the transitions of ions confined in magnetic field having same strength as Earth's magnetic field, is supported by the following observations.

1. The frequencies $15, 30, 45, 60, 75$ Hz having effect on primates are multiples of the same basic frequency $f = 15$ Hz, which turns out to be the cyclotron frequency of Ca^{2+} ion. That these

frequencies come in multiples is a direct signature of quantum: in classical world only basic frequency $f = 15$ Hz should have effects (forcing ions to rotational motion around field lines with this frequency.

2. Even multiples of 15 Hz have a weak but non-vanishing effect. Transitions are not possible at all in the lowest order of perturbation theory since the interaction Hamiltonian describing the transitions in question has non-vanishing matrix elements only between states of opposite parities in the dipole approximation applying when the wavelength of the radiation is much larger than the size of the radiating system [B20]. Odd and even values of n for cyclotron states have opposite parities so that Δn odd rule results. In higher orders of perturbation theory also transitions for which transition frequency is even multiple of the cyclotron frequency are possible. This observation provides additional strong support for the hypothesis that quantum transitions are involved.

There are however also objections.

1. The cyclotron energy scale is about 10^{-14} eV and ridiculously small as compared to the energy scale .086 eV defined by room temperature so that quantal effects should be masked completely by thermal noise.

2. Also ELF em fields at spin flip frequencies (Larmor frequencies) should induce transitions. These have not been reported.

3. The wave functions of ions in Earth's magnetic field are confined in a region of size of order

$$r_n \sim \sqrt{2n/eB} \ ,$$

which is of the order of cell size: macroscopic quantum state is in question. In fact, the value $.5 \times 10^{-4}$ Tesla for Earth's magnetic fields corresponds to the p-adic length scale $L(169) = 5$ μm rather precisely for minimal value of the magnetic flux quantized as $ZeBS = n2\pi$ obtained for $n = 1$ (S denotes the area of the flux tube) and $Z = 2e$. If one requires quantum classical correspondence, very large values of n are required and cyclotron radii would be much larger than flux tube radius.

A common resolution of all these objections is provided by large $\hbar$ phases and hierarchy of magnetic flux sheets with B scaling like $1/\hbar$ meaning that cyclotron frequencies scale down similarly and cyclotron energies remain invariant. Since spin is invariant under scalings of $\hbar$ spin flip energy scales down as $1/\hbar$ so that its contribution to magnetic energy is very small as compared to the cyclotron contribution and spin degrees of freedom are thermalized. Hence the system behaves classically in spin degrees of freedom. By the quantization of the magnetic flux, predicted by TGD also classically, the minimal radius of the magnetic flux tube for the magnetic field of Earth of cell size for ordinary value of $\hbar$ but scales like $\hbar$ if magnetic field remains invariant and flux quantization $BS = n2\pi\hbar$ implying $S \propto \hbar$ holds true. This implies consistency with classical theory for large values of $\hbar = \lambda^k \hbar_0$, $\lambda \simeq 2^{11}$.

A brief summary of the model

Some work is required to end up with the following interpretation based on a model for how the different levels of dark matter hierarchy communicate and control.

1. Ions with charge Z, mass m and spin S in the external magnetic field behave quantum mechanically like harmonic oscillator with energies quantized as

$$E = E_c + E_L \ , \quad E_c = (n + \frac{1}{2})\hbar\omega_c \ , \quad E_L = S_z \frac{g\omega_c}{2} \ , \quad \omega_c = \frac{ZeB}{m} \ \ (c = 1) \ . \tag{9.7.1}$$

The first contribution corresponds to cyclotron contribution. For a given value of n the component of angular momentum in the direction of B has $n + 1$ values $n, n-2, ..., -n$. E_L

denotes spin (Larmor) contribution. g is so called Lande factor which for free elementary fermions equals to $g = 2$. Since S_z is invariant under the scalings of $\hbar$, Larmor contribution is negligible as compared to cyclotron contribution for large values of $\hbar$. The contribution to energy coming from the free motion in the direction of magnetic field has not been written.

2. The model for high T_c superconductivity involving competition of two superconductivities, one associated with cell interior and second with cell membrane is the starting point. These phases coexist in a narrow range around critical temperature and 36-37 C range where the effects are observed is a good candidate for this range.

3. Experimental findings suggests strongly that external em field induces resonant transitions between cyclotron states: these transitions are identified as transitions inside the cell/nucleus or its fractally scaled up variant. For $k = 4$ level of dark matter hierarchy cyclotron energy scale turns out to be above the thermal energy $2.88T$ of photons at maximum intensity of black body radiation at room temperature for $A \leq 223Z$. Cyclotron radiation can drive charged particles to smaller space-time sheets and this is essential for the metabolism and this process is expected to be part of the interaction of ELF em fields with cell nucleus. The scale of cyclotron energies for $k = 4$ level of dark matter hierarchy is indeed turns out to be consistent with this assumption.

4. The ELF em field used in the experiments have electric fields strengths in two windows: one around 10^{-7} V/m and second corresponding to $1 - 10$ V/m. Even in the latter case the field is by a factor of order million weaker than membrane potential: the notion of many-sheeted space-time allows to understand why so weak fields can have effects on biomatter. Amplitude windows are a further mystery related with the interaction of ELF em fields with brain tissue: if ELF em field defines potential difference eV associated with a Josephson junction, one might understand this effect in terms of quantum jumps induced by Josephson current with frequency $f = ZeV/2\pi$.

5. Dark matter hierarchy leads to the hypothesis that there is entire hierarchy of EEGs generated as coherent photon states by Josephson currents associated with the Josephson junctions whose thickness scales as $\hbar$ and frequency scales as $1/\hbar$ so that cyclotron energy remains invariant and is above the thermal threshold. For each value of $\hbar$ there is also p-adic hierarchy corresponding to $k = 151, ..., 169$ with same Josephson frequency: these levels combine to form single block for dark matter hierarchy formed from the scaled up variants of this block. At least the magnetic flux tube structure of DNA and membrane structure appear as scaled up copies. The lowest level corresponds to cellular or nuclear membrane and ordinary value of $\hbar$.

6. Josephson current is of form $J \propto sin(2eVt + 2e\int V_1 dt)$ and its amplitude does not depend on the strength of the perturbation V_1. V_1 is same for all values of $\hbar$ but scales like $L(k)$ as function of p-adic length scale for given value of $\hbar$. Perturbation is represent as EEG pattern communicated to the magnetic body of fractally scaled up variant of cell or cell nucleus, which reacts appropriately. At the limit when the Josephson frequency $f_J^1 = 2eV_1/2\pi\hbar$ of perturbation satisfies $f_J^1 \gg f_c$, the amplitude of perturbation is coded to frequencies $f_\pm = f_J^1 \pm f_J$ in the EEG in a good approximation.

7. The response of the system is that of AND gate. V_1 induces in the neuronal nucleus or its scaled up counterpart cyclotron transitions if the frequency is correct. If this the case, cell nucleus opens up communication line receiving possible control signals from the magnetic body at higher level of hierarchy. V_1 induces in Josephson junctions effects if the amplitude is in the amplitude window guaranteeing that the frequencies $f_\pm$ belong to EEG resonance bands (or their scaled up variants. In this case magnetic body receives representation of V_1 as coherent photons and responds. If communication line is open the response induces in the cell nucleus gene translation and other activities necessary for the biological response. The model implies that cyclotron frequencies code for the biologically relevant information carried out by classical electric fields so that noise is eliminated very effectively. A detailed discussion of the model is left to [K22], where also the implications for the understanding of genetic code are discussed.

What about Z^0 magnetic transitions?

The idea that Z^0 magnetic magnetic transitions might be relevant for biomatter have been discussed already earlier. The identification of the sources of long ranged classical weak fields as dark matter forces however a profound modification of the earlier picture.

The TGD based models for atomic nuclei [K97] and condensed matter [K38] suggest strongly that the dark variant of $k=113$ copy of $k=89$ electro-weak physics is essential for understanding of not only the anomalies of water but also the basic properties of condensed matter. Also other copies of electro-weak physics with arbitrarily small weak mass scale are implied by the fact that long ranged classical weak fields are unavoidable in TGD Universe. Also the scaled down copies of color physics with arbitrarily low mass scales for quarks are a basic prediction of TGD.

If classical Z^0 magnetic field is present and if nuclei possess anomalous weak charges due to the presence of color bonds with quark and antiquark at their ends carrying non-vanishing net weak charges coupling to $k=113$ dark weak bosons, one must consider also Z^0 cyclotron frequencies given by

$$\begin{aligned} &\Omega = \tfrac{N(u\overline{d})}{A} \times Q_Z(u\overline{d}) \times \tfrac{g_Z B_Z}{eB} \times \Omega_p \ , \quad \Omega_p = \tfrac{eB}{m_p} \ , \\ &Q_Z(u\overline{d}) = \tfrac{1}{2} - sin^2(\theta_W) \ . \end{aligned} \tag{9.7.2}$$

Here $N(u\overline{d})$ is anomalous Z^0 charge of the nucleus due to weakly charged color bonds connecting nucleons with quark and antiquark at their ends using $u\overline{d}$ Z^0 charge $Q(u\overline{d})$ as unit. Ω_p is proton cyclotron frequency, which is about 300 Hz for $B=B_E=.5$ Gauss. The dependence on the Z^0 magnetic transition frequencies on the mass of nucleus is same as in the electromagnetic case.

The doubly dark weak bosons with weak length scale $L_w = 2^{22}L_w(113) = .2\ \mu$m should be key actors in TGD based model of living matter. Since the quantization of magnetic flux uses $\hbar$ as unit the quantum of Z^0 flux over a given area is multiplied by a factor 2^{22} for doubly dark weak bosons. Also the energy $\hbar\omega_c$ associated with the cyclotron frequency is multiplied by a factor 2^{22} so that energies are by a factor 2^{44} higher for cyclotron transitions in flux quantized Z^0 magnetic field than one might expect. In the case of dark quarks it would be natural to use $2(Q_Z(u\overline{d})$ as unit of charge in the quantization of magnetic flux so that the flux quantization reads $2Q_Z(u\overline{d})\int B_Z dA = n2^{22}\hbar 2\pi$.

Z^0 flux quanta with radius $L_w = .2\ \mu$m are expected to be of special interest. Consider the field corresponding to single flux quantum in this case. Using the fact that Earth's magnetic field taken to have nominal value.4742 Tesla corresponds to a single quantum of flux through a disk of radius $L(k=169)$, one obtains that the Z^0 cyclotron frequency and energy in this case are given by

$$\begin{aligned} \Omega_c(2^{22}\hbar) &= 2^{22}\Omega_c(\hbar)2^{22}\frac{N(u\overline{d})}{A} \times Q_Z(u\overline{d}) \times (\frac{L(169)}{L_w})^2\omega_p(B_{end}) \\ &\simeq \frac{N(u\overline{d})}{A} \times 750\ \ GHz \ , \\ E_c(2^{22}\hbar) &= 2^{44}E_c(\hbar) \simeq \frac{N(u\overline{d})}{A} \times 10^4\ \ eV \ . \end{aligned} \tag{9.7.3}$$

Here $B_{end} = .2$ Gauss corresponds to the endogenous magnetic field explaining the effects of ELF em fields on vertebrate brain: the value of B_{end} differs from the nominal value $B_E = .5$ Gauss for the Earth's magnetic field. Note that Ω_c and E_c do not depend on the unit of flux quantization. Cyclotron frequencies are in 10^{12} GHz range but energies in 10^4 eV range and corresponds to ordinary photon wavelength of about atomic length scale. In the earlier picture frequencies were in 10 Hz range. The energies involved are well above the thermal energy in room temperature. For the first level of dark matter hierarchy the frequency scale would be.375 GHz and energy scale 25 meV which is below thermal energy at room temperature.

Also ordinary nuclei containing charged color bonds would couple to dark weak bosons with weak length scale having nominal value $L_w = 2^{11}L_w(113) = 1$ Angstrom. In this case Z^0 magnetic fields would have 2^{11} stronger strength that in previous case and cyclotron energies would be same.

9.7.5 A General View About The Role Of Classical Fields In Quantum Control, Coordination And Communication

The following general overview about quantum communication and control emerges from the model for EEG hierarchy as correlate for dark matter hierarchy discussed in detail in [K37].

1. Cyclotron frequencies relate to the control of the biological body by the magnetic body and could be assigned with the magnetic flux sheets going through DNA since it is genome where protein synthesis is initiated and is thus the optimal intermediate step in the cellular control.

2. One of the basic functions of cell membranes is to perceive the chemical environment using various kinds of receptors as sensors. Neurons have specialized to receive symbolic representations of the sensory data of primary sensory organs about the situation in the external world. Receptor proteins would communicate cell level sensory input to the magnetic body via MEs parallel to magnetic flux tubes connecting them to the magnetic body. We ourselves would be in an abstract sense fractally scaled up counterparts of receptor proteins and associated with dark matter iono-lito Josephson junction connecting the parts of magnetosphere below litosphere and above magnetosphere.

3. This picture would explain why the temperature of brain must be in the narrow range 36-37 K to guarantee optimal functionality of the organism. If interior superconductivity is lost, magnetic body receives sensory data but is paralyzed since its desires cannot be realized. If boundary superconductivity is lost, magnetic body can move but is blind.

4. In the length scales below the weak length scale L_w also charged weak bosons behave as massless particles and the exchange of virtual W bosons makes possible a non-local charge transfer. Dark quark-antiquark pairs associated with the color bonds of the atomic nuclei can become charged via the emission of dark W boson and thus produce and exotic ion. The same can happen at the higher levels of dark matter hierarchy.

5. Massless extremals (MEs, topological light rays) serve as correlates for coherent states and Bose-Einstein condensates of dark bosons. Besides neutral massless extremals (MEs) TGD predicts also charged massless extremals obtained from their neutral counterparts by a mere color rotation (color and weak quantum numbers are not totally independent in TGD framework). The second non-local quantum control mechanism is based on em charge entanglement involving a superposition of ordinary ions/atoms and exotic ions connected by a W massless extremal joining magnetic body and biological body. In quantum jump this state would be reduced to exotic charge state with some probability increasing with the strength of the classical W field. Charged massless extremals could be seen as correlates for non-local quantum control by affecting charge equilibria whereas neutral MEs would serve as correlates for coordination and communication. Color charged MEs could also induce color charge polarization and flows of color charges and thus generate visual color qualia by the capacitor mechanism discussed in [K41].

6. These non-local quantal mechanisms can induce or change electromagnetic polarization in turn inducing ordinary charge flows and thus making possible quantum control of nervous system by magnetic body. The generation of nerve pulse could rely on the spontaneous state function reduction occurring for charge entangled state reducing the resting potential below the critical value by this kind of mechanism inducing charge transfer between cell interior and exterior. Also remote mental interactions, in particular telekinesis, might rely on this mechanism.

9.8 Dark Matter And Living Matter As Quantum Phases With Large Value Of Planck Constant

The TGD based model for topological quantum computation [B19] inspired the proposal that Planck constant might be dynamical and quantized in terms of logarithms of so called Beraha numbers $B_n = 4cos^2(\pi/n)$, $n \geq 3$ [K6]. Some recent discoveries in astrophysics [E6] and hadron physics [C20, C9], cold fusion anomaly [C8], etc. suggest that this might be the case. In particular, dark matter could correspond to quantum coherent phase with a large value of Planck constant [K92, K36]. The theoretical background for the quantization of Planck constant is discussed in [K118].

One implication is that living systems would correspond to a large value of Planck constant. This would mean that elementary quantum units correspond to systems consisting of very many elementary particles and that characteristic time and length scales are scaled up from those predicted by ordinary quantum theory so that macroscopic and macro-temporal quantum coherence become possible in the simplest manner one can imagine: indeed, the characteristic time and length scales are proportional to $\hbar$. This vision is discussed in detail in the [K36]. Here only a brief summary about basic ideas is given

9.8.1 Quantum Criticality, Hierarchy Of Dark Matters, And Dynamical $\hbar$

Quantum criticality is the basic characteristic of TGD Universe and quantum critical superconductors provide an excellent test bed to develop the ideas related to quantum criticality into a more concrete form.

Quantization of Planck constants and the generalization of the notion of embedding space

The recent geometric interpretation for the quantization of Planck constants is based on Jones inclusions of hyper-finite factors of type II_1 [K40].

1. Different values of Planck constant correspond to embedding space metrics involving scalings of M^4 *resp.* CP_2 parts of the metric deduced from the requirement that distances scale as $\hbar(M^4)$ *resp.* $\hbar(M^4)$. Denoting the Planck constants by $\hbar(M^4) = n_a\hbar_0$ and $\hbar(CP_2) = n_b\hbar_0$, one has that covariant metric of M^4 is proportional to n_b^2 and covariant metric of CP_2 to n_a^2. In Kähler action only the effective Planck constant $\hbar_{eff}/\hbar_0 = \hbar(M^4)/\hbar(CP_2)$ appears and by quantum classical correspondence same is true for Schödinger equation. Elementary particle mass spectrum is also invariant. Same applies to gravitational constant. The alternative assumption that M^4 Planck constant is proportional to n_b would imply invariance of Schrödinger equation but would not allow to explain Bohr quantization of planetary orbits and would to certain degree trivialize the theory.

2. M^4 and CP_2 Planck constants do not fully characterize a given sector $M^4_\pm \times CP_2$. Rather, the scaling factors of Planck constant given by the integer n characterizing the quantum phase $q = exp(i\pi/n)$ corresponds to the order of the maximal cyclic subgroup for the group $G \subset SU(2)$ characterizing the Jones inclusion $\mathcal{N} \subset \mathcal{M}$ of hyper-finite factors realized as subalgebras of the Clifford algebra of the "world of the classical worlds". This means that subfactor $\mathcal{N}$ gives rise to G-invariant WCW spinor s having interpretation as G-invariant fermionic states.

3. $G_b \subset SU(2) \subset SU(3)$ defines a covering of M^4_+ by CP_2 points and $G_a \subset SU(2) \subset SL(2,C)$ covering of CP_2 by M^4_+ points with fixed points defining orbifold singularities. Different sectors are glued together along CP_2 if G_b is same for them and along M^4_+ if G_a is same for them. The degrees of freedom lost by G-invariance in fermionic degrees of freedom are gained back since the discrete degrees of freedom provided by covering allow many-particle states formed from single particle states realized in G group algebra.

4. Phases with different values of scalings of M^4 and CP_2 Planck constants behave like dark matter with respect to each other in the sense that they do not have direct interactions except at criticality corresponding to a leakage between different sectors of embedding space glued together along M^4 or CP_2 factors. In large $\hbar(M^4)$ phases various quantum time and length scales are scaled up which means macroscopic and macro-temporal quantum coherence. In particular, quantum energies associated with classical frequencies are scaled up by a factor n_a/n_b which is of special relevance for cyclotron energies and phonon energies

(superconductivity). For large $\hbar(CP_2)$ the value of $\hbar_{eff}$ is small: this leads to interesting physics: in particular the binding energy scale of hydrogen atom increases by the factor n_b/n_a^2.

Preferred values of Planck constants

Number theoretic considerations favor the hypothesis that the integers corresponding to Fermat polygons constructible using only ruler and compass and given as products $n_F = 2^k \prod_s F_s$, where $F_s = 2^{2^s} + 1$ are distinct Fermat primes, are favored. The reason would be that quantum phase $q = exp(i\pi/n)$ is in this case expressible using only iterated square root operation by starting from rationals. The known Fermat primes correspond to $s = 0, 1, 2, 3, 4$ so that the hypothesis is very strong and predicts that p-adic length scales have satellite length scales given as multiples of n_F of fundamental p-adic length scale. $n_F = 2^{11}$ corresponds in TGD framework to a fundamental constant expressible as a combination of Kähler coupling strength, CP_2 radius and Planck length appearing in the expression for the tension of cosmic strings, and the powers of 2^{11} seem to be especially favored as values of n_a in living matter [K37].

How Planck constants are visible in Kähler action?

$\hbar(M^4)$ and $\hbar(CP_2)$ appear in the commutation and anti-commutation relations of various superconformal algebras. Only the ratio of M^4 and CP_2 Planck constants appears in Kähler action and is due to the fact that the M^4 and CP_2 metrics of the embedding space sector with given values of Planck constants are proportional to the corresponding Planck constants [K40]. This implies that Kähler function codes for radiative corrections to the classical action, which makes possible to consider the possibility that higher order radiative corrections to functional integral vanish as one might expect at quantum criticality. For a given p-adic length scale space-time sheets with all allowed values of Planck constants are possible. Hence the spectrum of quantum critical fluctuations could in the ideal case correspond to the spectrum of $\hbar$ coding for the scaled up values of Compton lengths and other quantal lengths and times. If so, large $\hbar$ phases could be crucial for understanding of quantum critical superconductors, in particular high T_c superconductors.

Phase transitions changing the level in dark matter hierarchy

The identification of the precise criterion characterizing dark matter phase is far from obvious. TGD actually suggests an infinite number of phases which are dark relative to each other in some sense and can transform to each other only via a phase transition which might be called de-coherence or its reversal and which should be also characterized precisely.

A possible solution of the problem comes from the general construction recipe for S-matrix. Fundamental vertices correspond to partonic 2-surfaces representing intersections of incoming and outgoing light-like partonic 3-surfaces.

1. If the characterization of the interaction vertices involves all points of partonic 2-surfaces, they must correspond to definite value of Planck constant and more precisely, definite groups G_a and G_b characterizing dark matter hierarchy. Particles of different phases could not appear in the same vertex and a phase transition changing the particles to each other analogous to a de-coherence would be necessary.

2. If transition amplitudes involve only a discrete set of common orbifold points of 2-surface belonging to different sectors then the phase transition between relatively dark matters can be described in terms of S-matrix. It seems that this option is the correct one. In fact, also propagators are essential for the interactions of visible and dark matter and since virtual elementary particles correspond at space-time level CP_2 type extremals with 4-dimensional CP_2 projection, they cannot leak between different sectors of embedding space and therefore cannot mediate interactions between different levels of the dark matter hierarchy. This would suggest that the direct interactions between dark and ordinary matter are very weak.

If the matrix elements for real-real partonic transitions involve all or at least a circle of the partonic 2-surface as stringy considerations suggest [K28], then one would have clear distinction between quantum phase transitions and ordinary quantum transitions. Of course, the fact that the points which correspond to zero of Riemann Zeta form only a small subset of points common to real partonic 2-surface and corresponding p-adic 2-surface, implies that the rate for phase transition is in general small. On the other hand, for the non-diagonal S-matrix elements for ordinary transitions would become very small by almost randomness caused by strong fluctuations and the rate for phase transition could begin to dominate.

Transition to large $\hbar$ phase and failure of perturbation theory

A further idea is that the transition to large $\hbar$ phase occurs when perturbation theory based on the expansion in terms of gauge coupling constant ceases to converge: Mother Nature would take care of the problems of theoretician. The transition to large $\hbar$ phase obviously reduces gauge coupling strength α so that higher orders in perturbation theory are reduced whereas the lowest order "classical" predictions remain unchanged. A possible quantitative formulation of the criterion is that maximal 2-particle gauge interaction strength parameterized as $Q_1Q_2\alpha$ satisfies the condition $Q_1Q_2\alpha \simeq 1$.

A justification for this picture would be that in non-perturbative phase large quantum fluctuations are present (as functional integral formalism suggests). At space-time level this would mean that space-time sheet is near to a non-deterministic vacuum extremal. At parton level this would mean that partonic surface contains large number of CP_2 orbifold points so that S-matrix elements for the phase transition becomes large. At certain critical value of coupling constant strength one expects that the transition amplitude for phase transition becomes very large.

Dark matter and standard physics

The hierarchy of phases behaving like dark or partially dark matter with respect to the ordinary matter [?] seem to be essential for the understanding of even ordinary hadronic, nuclear and condensed matter physics [?, K97, K38]. This strengthens the motivations for finding whether dark matter might be involved with quantum critical super-conductivity.

9.8.2 Hadronic Black Holes And New View About Dark Matter

Important steps in the development of ideas were stimulated by the findings made during period 2002-2005 in Relativist Heavy Ion Collider (RHIC) in Brookhaven compared with the discovery of America and for full reason [C20, C9]. In particular, the observed production of black-hole like object in heavy ion collisions support the view that in non-perturbative phase of QCD matter possesses large value of $\hbar$ and becomes thus analogous to dark matter. Surprisingly precise analogies with black hole formation and evaporation or equivalently with big crush followed by big bang describable as scaled down version of TGD inspired cosmology, emerge.

9.8.3 Dark Atoms And Dark Cyclotron States

The development of the notion of dark atom involves many side tracks which make me blush. The first naïve guess was that dark atom would be obtained by simply replacing Planck constant with its scaled counterpart in the basic formulas and interpreting the results geometrically. After some obligatory twists and turns it became clear that this assumption is indeed the most plausible one. The main source of confusion has been the lack of precise view about what the hierarchy of Planck constants means at the level of embedding space at space-time.

The rules are very simple when one takes the singular coverings assigned to the many-valuedness of the time-derivatives of embedding space coordinates as functions of canonical momentum densities as a starting point.

1. The mass and charge of electron are fractionized as is also the reduced mass in Schrödinger equation. This implies the replacements $e \rightarrow e/r$, $m \rightarrow m/r$, and $\hbar \rightarrow r\hbar_0$, $r = n_an_b$, in the general formula for the binding energy assigned with single sheet of the covering. If maximal number n_an_b are present corresponding to a full "Fermi sphere", the total binding energy is r times the binding energy associated with single sheet.

2. In the case of hydrogen atom the proportionality $E \propto m/\hbar^2$ implies that the binding energy for single sheet of the covering scales as $E \to E/(n_a n_b)^3$ and maximal binding energy scales as $E \to E/(n_a n_b)^2$. This conforms with the naïve guess. For high values of the nuclear charge Z it can happen that the binding energy is larger than the rest mass and fractionization might take place when binding energy is above critical fraction of the rest mass.

3. In the case of cyclotron energies one must must decide what happens to the magnetic flux. Magnetic flux quantization states that the flux is proportional to $\hbar$ for each sheet separately. Hence one has $\Phi \to r\Phi$ for each sheet and the total flux scales as r^2. Since the dimensions of the flux quantum are scaled up by r the natural scaling of the size of flux quantum is by r^2. Therefore the quantization of the magnetic flux requires the scaling $B \to B/r$. The cyclotron energy for single sheet satisfies $E \propto \hbar qB/m$ and since both mass m and charge q become fractional, the energy E for single sheet remains invariant whereas total cyclotron energy is scaled up by r in accordance with the original guess and the assumption used in applications.

4. Dark cyclotron states are expected to be stable up to temperatures which are r times higher than for ordinary cyclotron states. The states of dark hydrogen atoms and its generalizations are expected to be stable at temperatures scaled down by $1/r^2$ in the first approximation.

5. Similar arguments allow to deduce the values of binding energies in the general case once the formula of the binding energy given by standard quantum theory is known.

The most general option option allows fractional atoms with proton and electron numbers varying from $1/r$ to 1. One can imagine also the possibility of fractional molecules. The analogs of chemical bonds between fractional hydrogen atoms with $N-k$ and k fractional electrons and protons can be considered and would give rise to a full shell of fractional electrons possessing an exceptional stability. These states would have proton and electron numbers equal to one.

Catalytic sites are one possible candidate for fractal electrons and catalyst activity might be perhaps understood as a strong tendency of fractal electron and its conjugate to fuse to form an ordinary electron.

9.8.4 How Dark Matter And Visible Matter Interact?

The hypothesis that the value of $\hbar$ is dynamical, quantized and becomes large at the verge of a transition to a non-perturbative phase in the ordinary sense of the word has fascinating implications. In particular, dark matter, would correspond to a large value of $\hbar$ and could be responsible for the properties of the living matter. In order to test the idea experimentally, a more concrete model for the interaction of ordinary matter and dark matter must be developed and here of course experimental input and the consistency with the earlier quantum model of living matter is of considerable help.

How dark photons transform to ordinary photons?

The transitions of dark atoms naturally correspond to coherent transitions of the entire dark electron BE condensate and thus generate N_{cr} dark photons and behave thus like laser beams. Dark photons do not interact directly with the visible matter. An open question is whether even ordinary laser beams could be identified as beams of dark photons: the multiple covering property at the level of embedding space and the fact that MEs are possible in all sectors suggests that this is not the case. Note that the transition from dark to ordinary photons implies the scaling of wave length and thus also of coherence length by a factor n_b/n_a.

Dark $\leftrightarrow$ visible transition should have also a space-time correlate. The so called topological light rays or MEs ("massless extremals") represent a crucial deviation of TGD from Maxwell's ED and have all the properties characterizing macroscopic classical coherence. Therefore MEs are excellent candidates for the space-time correlate of BE condensate of dark photons.

MEs carry in general a superposition of harmonics of some basic frequency determined by the length of ME. A natural expectation is that the frequency of classical field corresponds to the generalized de Broglie frequency of dark photon and is thus $\hbar/\hbar_s$ times lower than for ordinary photons. In completely analogous manner de Broglie wave length is scaled up by $k = \hbar_s/\hbar$. Classically the decay of dark photons to visible photons would mean that an oscillation with frequency f inside topological light ray transforms to an oscillation of frequency f/k such that the intensity of the oscillation is scaled up by a factor k. Furthermore, the ME in question could naturally decompose into $1 < N_{cr} \leq 137$ ordinary photons in case that dark atoms are in question. Of course also MEs could decay to lower level MEs and this has an interpretation in terms of hierarchy of dark matters to be discussed next.

About the criterion for the transition increasing the value of Planck constant

An attractive assumption is that the transition to dark matter phase occurs when the interaction strength satisfies the criticality condition $Q_1Q_2\alpha \simeq 1$. A special case corresponds to self interaction with $Q_1 = Q_2$. This condition applies only to gauge interactions so that particles can be characterized by gauge charges. A more general characterization would be that transition occurs when perturbation theory ceases to converge. The criterion cannot be applied to phenomenological QFT description of strong force in terms of, say, pion exchange.

Some examples are in order to test this view.

1. Transition from perturbative phase in QCD to hadronic phase is the most obvious application. The identification of valence quarks and gluons as dark matter would predict for them QCD size ($k = 107$ space-time sheet) of about electron Compton length. This does not change the QCD cross sections in the lowest order perturbation theory but makes them excellent predictions. It also provides completely new view about how color force determines the nuclear strong force indeed manifesting itself as long ranged harmonic oscillator potential, the long range of which becomes manifest in case of neutron halos of size of 2.5×10^{-14} m [C21]. One can also understand tetraneutron in this framework. This criterion applies also in QCD plasma and explains the formation of liquid like color glass condensate detected in RHIC [C20]. A possible interpretation for QCD size would be as a length of the cylindrical magnetic walls defining the magnetic body associated with u and d type valence quarks, nucleons, and nuclei. There is no need to assume that conformal weights are complex in this phase.

2. QCD size of quark must be distinguished from the electromagnetic size of quark associated with $k = 113$ space-time sheets of u and d quarks and assignable to the height of the magnetic body and defining the length scale of flux tubes feeding quark charges to $k = 113$ space-time sheets.

3. In the case of atomic nuclei the criterion would naturally apply to the electromagnetic interaction energy of two nucleon clusters inside nucleus or to self energy ($Q^2\alpha_{em} = 1$). Quite generally, the size of the electromagnetic $k = 113$ space-time sheet would increase by a $n_F = 2^k \prod_s F_s$, where F_s are different Fermat primes (the known ones being $3, 5, 17, 257, 2^{16} + 1$), in the transition to large $\hbar$ phase. Especially interesting values of n_F seem to be of form $n_F = 2^{k11}$ and possibly also $n_F = 2^{k11} \prod_s F_s$. Similar criterion would apply in the plasma phase. Note that many free energy anomalies involve the formation of cold plasma [K110].

The criterion would give in the case of single nucleus and plasma $Z \geq 12$ if the charges are within single space-time sheet. This is consistent with cold fusion involving Palladium nuclei [C8]. Since u and d quarks have $k = 113$, they both and thus both neutrons and protons could make a transition to large $\hbar$ phase. This is consistent with the selection rules of cold fusion since the production of ^3He involves a phase transition pnp$_d$ $\rightarrow$ pnp and the contraction of p_d to p is made un-probable by the Coulomb wall whereas the transition nnp$_d$ $\rightarrow$nnp producing tritium does not suffer from this restriction.

Strong and weak physics of nuclei would not be affected in the phase transition. Electromagnetic perturbative physics of nuclei would not be affected in the process in the lowest order in $\hbar$ (classical approximation) but the height of the Coulomb wall would be reduced by a factor $1/n_F$ by the increase in the electromagnetic size of the nucleus. Also Pd nuclei could make the transition and Pd nuclei could catalyze the transition in the case the deuterium nuclei.

9.8.5 Dark Matter And Exotic Color And Electro-Weak Interactions

The presence of classical electro-weak and color gauge fields in all length scales is an unavoidable prediction of TGD and the interpretation in terms of hierarchy of dark matters in some sense is also more or less unavoidable.

Does dark matter provide a correct interpretation of long ranged classical electro-weak gauge fields?

For two decades one of the basic interpretational challenges of TGD has been to understand how the un-avoidable presence of long range classical electro-weak gauge fields can be consistent with the small parity breaking effects in atomic and nuclear length scales. Also classical color gauge fields are predicted, and I have proposed that color qualia correspond to increments of color quantum numbers [K41] . The proposed model for screening cannot banish the unpleasant feeling that the screening cannot be complete enough to eliminate large parity breaking effects in atomic length scales so that one one must keep mind open for alternatives.

p-Adic length scale hypothesis suggests the possibility that both electro-weak gauge bosons and gluons can appear as effectively massless particles in several length scales and there indeed exists evidence that neutrinos appear in several scaled variants [C19] (for TGD based model see [K56]).

This inspires the working hypothesis that long range classical electro-weak gauge and gluon fields are correlates for light or massless dark electro-weak gauge bosons and gluons.

1. In this kind of scenario ordinary quarks and leptons could be essentially identical with their standard counterparts with electro-weak charges screened in electro-weak length scale so that the problems related to the smallness of atomic parity breaking would be trivially resolved.

2. In condensed matter blobs of size larger than neutrino Compton length (about 5 μm if $k = 169$ determines the p-adic length scale of condensed matter neutrinos) the situation could be different. Also the presence of dark matter phases with sizes and neutrino Compton lengths corresponding to the length scales defined as scaled up electronic Compton lengths $L_e(k)$, $k = 151, 157, 163, 167$ in the range 10 nm-2.5 μm are suggested by the number theoretic considerations (these values of k correspond to so called Gaussian Mersennes [K48]). Only a fraction of the condensed matter consisting of regions of size $L_e(k)$ need to be in the dark phase.

3. Dark quarks and leptons would have masses essentially identical to their standard model counterparts. Only the electro-weak boson masses which are determined by a different mechanism than the dominating contribution to fermion masses [K56, K56] would be small or vanishing.

4. The large parity breaking effects in living matter would be due to the presence of dark nuclei and leptons. Later the idea that super-fluidity corresponds to Z^0 super-conductivity will be discussed: it might be that also super-fluid phase corresponds to dark neutron phase.

The basic prediction of TGD based model of dark matter as a phase with a large value of Planck constant is the scaling up of various quantal length and time scales. A simple quantitative model for condensed matter with large value of $\hbar$ predicts that $\hbar$ is by a factor $\sim 2^{11}$ determined by the ratio of CP_2 length to Planck length larger than in ordinary phase meaning that the size of dark neutrons would be of order atomic size. In this kind of situation single order parameter would characterize the behavior of dark neutrinos and neutrons and the proposed model could apply as such also in this case.

Dark photon many particle states behave like laser beams decaying to ordinary photons by de-coherence meaning a transformation of dark photons to ordinary ones. Also dark electro-weak bosons and gluons would be massless or have small masses determined by the p-adic length scale in question. The decay products of dark electro-weak gauge bosons would be ordinary electro-weak bosons decaying rapidly via virtual electro-weak gauge boson states to ordinary leptons. Topological light rays ("massless extremals") for which all classical gauge fields are massless are natural space-time correlates for the dark boson laser beams. Obviously this means that the basic difference between the chemistries of living and non-living matter would be the absence of electro-weak symmetry breaking in living matter (which does not mean that elementary fermions would be massless). If both nuclear neutrons and neutrinos are in dark phase, it is possible to achieve a rather complete local cancelation of Z^0 charge density.

The model for neutrino screening was developed years before the ideas about the identification of the dark matter emerged. The generalization of the discussion to the case of dark matter option should be rather trivial and is left to the reader as well as generalization of the discussion of the effects of long range Z^0 force on bio-chemistry.

Criterion for the presence of exotic electro-weak bosons and gluons

Classical gauge fields directly are space-time correlates of quantum states. The gauge fields associated with massless extremals ("topological light rays") decompose to free part and a part having non-vanishing divergence giving rise to a light-like Abelian gauge current. Free part would correspond to Bose-Einstein condensates and current would define a coherent state of dark photons.

The dimension D of the CP_2 projection of the space-time sheet serves as a criterion for the presence of long ranged classical electro-weak and gluon fields. D also classifies the (possibly asymptotic) solutions of field equations [K16].

1. For $D = 2$ induced gauge fields are Abelian and induced Kähler form vanishes for vacuum extremals: in this case classical em and Z^0 fields are proportional to each other. The non-vanishing Kähler field implies that induced gluon fields are non-vanishing in general. This raises the question whether long ranged color fields and by quantum classical correspondence also long ranged QCD accompany non-vacuum extremals in all length scales. This makes one wonder whether color confinement is possible at all and whether scaled down variants of QCD appear in all length scales.

   The possibility to add constants to color Hamiltonians appearing in the expression of the classical color gauge fields allows to have vanishing color charges in the case of an arbitrary space-time sheet. The requirement that color quantum numbers of the generator vanish allows to add the constant only to the Hamiltonians of color hyper charge and isospin so that for $D = 2$ extremals color charges can be made vanishing. This might allow to understand how color confinement is consistent with long ranged induced Kähler field.

2. For $D \geq 3$ all classical long ranged electro-weak fields and non-Abelian color fields are present. This condition is satisfied when electric and magnetic fields are not orthogonal and the instanton density $A \wedge J$ for induced Kähler form is non-vanishing. The rather strong conclusion is that in length scales in which exotic electro-weak bosons are not present, one has $D = 2$ and gauge fields are Abelian and correspond trivially to fixed points of renormalization group realized as a hydrodynamic flow at space-time sheets [L42].

Quantum classical correspondence suggests the existence of electro-weak gauge bosons with mass scale determined by the size of the space-time sheets carrying classical long range electro-weak fields. This would mean the existence of new kind of gauge bosons.

The obvious objection is that the existence of these gauge bosons would be reflected in the decay widths of intermediate gauge bosons. The remedy of the problem is based on the notion of space-time democracy suggested strongly by the fact that the interactions between space-time sheets possessing different p-adic topologies proceed with very slow rates simply because the number of common rational (algebraic points of partonic 2-surfaces appearing in the vertex is small.

For light exotic electro-weak bosons also the corresponding leptons and quarks would possess a large weak space-time sheet but lack the ordinary weak partonic 2-surface so that there would be no direct coupling to electro-weak gauge bosons. These space-time sheets are dark in weak sense but need not have a large value of $\hbar$. This picture implies the notion of partial darkness since any space-time sheets with different ordinary of Gaussian primes are dark with respect to each other.

Do Gaussian Mersennes define a hierarchy of dark electro-weak physics?

Gaussian Mersennes are defined as Gaussian primes of form $g_n = (1+i)^n - 1$, where n must be prime. They have norm squared $g\overline{g} = 2^n - 1$. The list of the first Gaussian Mersennes corresponds to the following values of n.

2, 3, 5, 7, 11, 19, 29, 47, 73, 79, 113, 151, 157, 163, 167, 239, 241, 283, 353, 367, 379, 457, 997, 1367, 3041, 10141, 14699, 27529, 49207, 77291, 85237, 106693, 160423 and 203789.

The Gaussian primes $k = 113, 151, 157, 163, 167$ correspond to length scales which are of most obvious interest but in TGD framework one cannot exclude the twin prime $239, 241$ corresponds to length scales $L_e(k) \simeq 160$ km and 320 km. Also larger primes could be of relevant for bio-systems and consciousness. Also the secondary and higher length scales associated with $k < 113$ could be of importance and their are several length scales of this kind in the range of biologically interesting length scales. Physics and biology inspired considerations suggests that particular Gaussian primes correspond to a particular kind of exotic matter, possibly also to large $\hbar$ phase.

$k = 113$ corresponds to the electromagnetic length scale of u and d quarks and nuclear p-adic length scale. For dark matter these length scales are scaled up by a factor $\sim 2^{11}n$, where n is an integer. For $k = 113$ one obtains atomic length scale.8 A for $n = 1$. $k = 151, 153, 163, 167$ correspond to biologically important p-adic length scales for which electron Compton lengths vary in the range 10 nm-2.5 μm with the scaled up Compton lengths varying in the range 2 μm- 5 mm.

On basis of biological considerations (large parity breaking in living matter) there is a temptation to assign to these length scales a scaled down copy of electro-weak physics and perhaps also of color physics. The mechanism giving rise to these states would be a phase transition transforming the ordinary $k = 89$ Mersenne of weak space-time sheets to a Gaussian Mersenne and thus increasing its size dramatically.

If given space-time sheet couples considerably only to space-time sheets characterized by same prime or Gaussian prime, the bosons of these physics do not couple directly to ordinary particles, and one avoids consistency problems due to the presence of new light particles (consider only the decay widths of intermediate gauge bosons [K60]) even in the case that the loss of asymptotic freedom is not assumed.

A question arises about the interpretation of structures of the predicted size. The strong interaction size of u and d quarks, hadrons, and nuclei is smaller than $L(k = 113) \simeq 2 \times 10^{-4}$ m for even heaviest nuclei if one accepts the formula $R \sim A^{1/3} \times 1.5 \times 10^{-15}$ m. A natural interpretation for this length scale would be as the size of the field body/magnetic body of system defined by its topologically quantized gauge fields/magnetic parts of gauge fields. The (possibly dark) p-adic length scale characterizes also the lengths of flux tubes feeding gauge fluxes from elementary particle to the space-time sheet in question. The de-localization due these flux tubes in p-adic length scale in question would determine the scale of the contribution to the mass squared of the system as predicted by p-adic thermodynamics.

9.8.6 Dark Matter And Living Matter

The hypothesis that the value of $\hbar$ is dynamical, quantized and becomes large at the verge of a transition to a non-perturbative phase in the ordinary sense of the word has fascinating implications. In particular, dark matter, would correspond to a large value of $\hbar$ and could be responsible for the properties of the living matter. In order to test the idea experimentally, a more concrete model for the interaction of ordinary matter and dark matter must be developed and here of course experimental input and the consistency with the earlier quantum model of living matter is of considerable help.

Hierarchy of dark matters and hierarchy of minds

The notion of dark matter is only relative concept in the sense that dark matter is invisible from the point of view of the ordinary matter. One can imagine an entire hierarchy of dark matter structures corresponding to the hierarchy of space-time sheets for which p-adic length scales differ by a factor $1/v_0 \sim 2^{11}$. The BE condensates of N_{cr} ordinary matter particles would serve as dynamical units for "dark dark matter" invisible to the dark matter. The above discussed criticality criterion can be applied at all levels of the hierarchy to determine the value of the dynamical interaction strength for which BE condensates of BE condensates are formed.

This hierarchy would give rise to a hierarchy of the values of $\hbar_n/\hbar$ coming as powers of v_0^{-n} as well as a hierarchy of wavelengths with same energy coming as powers or v_0^n. For zero point kinetic energies proportional to $\hbar^2$ this hierarchy would come in powers of v_0^{-2n}, for magnetic interaction energies proportional to $\hbar$ the hierarchy would come in powers v_0^{-n} whereas for atomics energy levels the hierarchy would come in powers of v_0^{2n} (assuming that this hierarchy makes sense).

The most interesting new physics would emerge from the interaction between length scales differing by powers of v_0 made possible by the decay of BE condensates of dark photons to ordinary photons having wavelength shorter by a factor $\sim v_0$. This interaction could provide the royal road to the quantitative understanding how living matter manages to build up extremely complex coherent interactions between different length and time scales.

In the time domain dark matter hierarchy could allow to understand how moments of consciousness organize to a hierarchy with respect to the time scales of moment of consciousness coming as 2^{11k} multiples of CP_2 time scale. Even human life span could be seen as single moment of consciousness at $k = 14^{th}$ level of the dark matter hierarchy whereas single day in human life would correspond to $k = 12$.

Realization of intentional action and hierarchy of dark matters

How long length scales are able to control the dynamics in short length scales so that the extremely complex process extending down to atomic length scales realizing my intention to write this word is possible. This question has remained without a convincing answer in the recent day biology and there strong objections against the idea that this process is planned and initiated at neuronal level.

I have proposed a concrete mechanism for the realization of intentional action in terms of time mirror mechanism involving the emission of negative energy photons and proceeding as a cascade in a reversed direction of geometric time from long to short length scales [**?**]. This cascade would induce as a reaction analogous processes proceeding in the normal direction of geometric time as a response and would correspond to the neural correlates of intentional action in very general sense of the word.

The counterparts for the negative energy signals propagating to the geometric past would be phase conjugate (negative energy) laser beams identifiable as Bose-Einstein condensates of dark photons. In the time reflection these beams would transform to positive energy dark matter photons eventually decaying to ordinary photons. The space-time correlate would be MEs decaying into MEs and eventually to CP_2 type extremals representing ordinary photons.

The realization of intentional action as desires of boss expressed to lower level boss would naturally represented the decay of the phase conjugate dark laser beam to lower level laser beams decaying to lower level laser beams decaying to.... This would represent the desire for action whereas the time reflection at some level would represent the realization desire as stepwise decay to lower level laser beams and eventually to ordinary photons. The strong quantitative prediction would be that these levels correspond to a length and time scale hierarchies coming in powers of $1/v_0 \sim 2^{11}$.

Wave-length hierarchy, coherent metabolism, and proton-electron mass ratio

The fact that a given wavelength length corresponds to energies related to each other by a scaling with powers of v_0 provides a mechanism allowing to transfer energy from long to short long scales by a de-coherence occurring either in the standard or reversed direction of geometric time. De-coherence in the reversed direction of time would be associated with mysterious looking processes like self-assembly allowing thus an interpretation as a normal decay process in reversed time direction.

It is perhaps not an accident that the value of $v_0 \simeq 4.6 \times 10^{-4}$ is not too far from the ratio of $m_e/m_p \simeq 5.3 \times 10^{-4}$ giving the ratio of zero point kinetic energies of proton and electron for a given space-time sheet. This co-incidence could in principle make possible a metabolic mechanism in which dark protons and ordinary electrons co-operate in the sense that dark protons generate dark photon BE condensates with wave length λ transforming to ordinary photons with wavelength $v_0\lambda$ absorbed by ordinary electrons.

Some examples are in order to illustrate these ideas.

1. As already found, in the case of dark atoms the scaling of binding energies as $1/\hbar^2$ allows the coupling of $\sim$ 9 cm scale of brain hemisphere with the length scale ~ 50 μm of large

neuron. $N_{cr} \leq 137$ ordinary IR photons would be emitted in single burst and interacting with neuron.

2. For a non-relativistic particle in a box of size L the energy scale is given by $E_1 = \hbar^2\pi^2/2mL^2$ so that the visible photons emitted would have energy scaled up by a factor $(\hbar_s/\hbar)^2 \simeq 4\times 10^6$. The collective dropping of N_{cr} dark protons to larger space-time sheet would liberate a laser beam of dark photons with energy equal to the liberated zero point kinetic energy. For instance, for the p-adic length scale $L(k = 159 = 3 \times 53) \simeq .63$ μm this process would generate laser beam of IR dark photons with energy $\sim .5$ eV also generated by the dropping of ordinary protons from $k = 137$ atomic space-time sheet. There would thus be an interaction between dark protons in cell length scale and ordinary protons in atomic length scale. For instance, the dropping of dark protons in cell length scale could induce driving of protons back to the atomic space-time sheet essential for the metabolism [K49]. Similar argument applies to electrons with the scale of the zero point kinetic energy about 1 keV.

   In many-sheeted space-time particles topologically condense at all space-time sheets having projection to given region of space-time so that this option makes sense only near the boundaries of space-time sheet of a given system. Also p-adic phase transition increasing the size of the space-time sheet could take place and the liberated energy would correspond to the reduction of zero point kinetic energy. In this case the process would occur coherently for all particles. Particles could be transferred from a portion of magnetic flux tube portion to another one with different value of magnetic field and possibly also of Planck constant h_{eff} so that cyclotron energy would be liberated.

   In the sequel the early version of the model assigning metabolic energy quantum to the dropping of protons is only considered. In [K80] a model of metabolism associating the metabolic energy quantum to the change of cyclotron energy is discussed.

3. If the energy spectrum associated with the conformational degrees of freedom of proteins, which corresponds roughly to a frequency scale of 10 GHz remains also invariant in the phase transition to dark protein state, coherent emissions of dark photons with microwave wave lengths would generate ordinary infrared photons. For instance, metabolic energy quanta of $\sim .5$ eV could result from macroscopic Bose-Einstein condensates of 58 GHz dark photons resulting from the oscillations in the conformational degrees of freedom of dark proteins. A second option is that the conformal energies are scaled by $\hbar_s/\hbar$ (ω would remain invariant). In this case these coherent excitations would generate ordinary photons with energy of about 1 keV able to drive electrons back to the atomic $k = 137$ space-time sheet.

4. Since magnetic flux tubes have a profound role in TGD inspired theory of consciousness, it is interesting to look also for the behavior of effective magnetic transition energies in the phase transition to the dark matter phase. This transition increases the scale of the magnetic interaction energy so that anomalously large magnetic spin splitting $\hbar_s eB/m$ in the external magnetic field could serve as a signature of dark atoms. The dark transition energies relate by a factor $\hbar_s/\hbar$ to the ordinary magnetic transition energies.

For instance, in the magnetic field of Earth with a nominal value $.5 \times 10^{-4}$ Tesla dark electron cyclotron frequency is 6×10^5 Hz and corresponds to ordinary microwave photon with frequency ~ 1.2 GHz and wavelength $\lambda \simeq 25$ cm. For proton the cyclotron frequency of 300 Hz would correspond to energy of ordinary photon with frequency of 6×10^5 Hz and could induce electronic cyclotron transitions and spin flips in turn generating for instance magneto-static waves.

It is easy to imagine a few step dark matter hierarchy connecting EEG frequencies of dark matter with frequencies of visible light for ordinary photons. This kind of hierarchy would give considerable concreteness for the notion of magnetic body having size scale of Earth.

A connection with the scaling law of homeopathy

The value of the parameter $1/v_0 \simeq 2083$ is essentially the ratio of CP_2 radius and Planck length scale (as also the ratio of Compton lengths of electron and proton) and rather near to $2^{11} = 2048$. Interestingly, much larger number $2 \times 10^{11} \simeq 25 \times 2^{33}$ appears in the simplest form for what I have christened the scaling law of homeopathy [K44]. This rule has been proposed on basis of experimental findings [I31] but has no convincing theoretical justification. The scaling law of homeopathy states that high frequency em radiation transforms to a low frequency radiation and vice versa preferably with the frequency ratio $f_{high}/f_{low} \simeq 2 \times 10^{11}$.

In [K44] I have discussed some mechanisms for the transformation of high energy photons to low energy photons consistent with the rule and proposed a generalization of the rule based on p-adic length scale hypothesis. For instance, high energy visible photons of frequency f could induce an excitation of the receiving system having same frequency, propagating with velocity $\beta = v/c \simeq 10^{-11}/2$, and having wave length equal $\lambda_0 = f/v = \lambda/\beta$. This excitation would in turn couple to photons of wavelength λ_0 and frequency $f_0 = \beta f$.

A much deeper explanation for the scaling law of homeopathy is based on the quantization of Planck constant. Number theoretical arguments suggest a general formula for the allowed values of λ [K40] as $\lambda = n$ where n characterizes the quantum phase $q = exp(i\pi/n)$ characterizing Jones inclusion [K118]. The values of n for which quantum phase is expressible using only iterated square root operation are number theoretically preferred and correspond to integers n expressible as $n = 2^k \prod_n F_{s_n}$, where $F_s = 2^{2^s} + 1$ is Fermat prime and each of them can appear only once. $n = 2^{11}$ obviously satisfies this condition. The lowest Fermat primes are $F_0 = 3, F_1 = 5, F_2 = 17, F_3 = 257, F_4 = 2^{16} + 1$. The prediction is that also n-multiples of p-adic length scales are possible as preferred length scales.

The scaling factor 2×10^{11} corresponds with 1.5 per cent accuracy to the integer $n_F = 2^{36} \times 3 \simeq 2.03 \times 10^{11}$ defining a Fermat polygon. This suggests an interpretation in terms of a decay of dark photon with a given wave-length to a bundle of n_F ordinary photons with the same wavelength. The energy of the dark photon would be by a factor n_F higher. This process could serve as an effective tool of bio-control. Dark photon could also transform to an ordinary photon with wavelength shorter by factor $1/n_F$. There is a lot of evidence that the powers of $n = 2^{11}$ define preferred scalings of $\hbar$: n_F corresponds to $n_F = 2^{3\times 11} \times 24$ which suggests that also the scale factors $n_F = 2^{k\times 11} \times 24$ could be favored. Quite generally, integers n_F defining Fermat polygons are a reasonable guess for the generalization of the scaling law of homeopathy and the search for these scaling factors could provide an experimental means of identifying the values of Planck constant relevant for living matter.

The time units of everyday life could reflect the properties of the dark matter hierarchy responsible for the control of living matter, in particular those of the sub-hierarchy defined by Fermat polygons. Indeed, one year corresponds to $n_F = 4\times 3$ months, one month to $n_F = 2\times 3\times 5$ days, one day to $n_F = 8 \times 3$ hours, one hour to $n_F = 60 = 4 \times 3 \times 5$ minutes, and one minute to $n_F = 60$ seconds.

A connection with bio-photons

The biologically active radiation at UV energies was first discovered by Russian researcher Gurwitz using a very elegant experimental arrangement [I26]. Gurwitz christened this radiation mitogenetic radiation since it was especially intense during the division of cell.

A direct proof for the biological activity of mitogenetic radiation consisted of a simple experiment in which either quartz or glass plate was put between two samples. The first sample contained already growing onion roots whereas the second sample contained roots which did not yet grow. In the case of quartz plate no stimulation of growth occurred unlike for glass plate. Since quartz is not transparent to UV light whereas the ordinary glass is, the conclusion was that the stimulation of growth is due to UV light.

The phenomenon was condemned by skeptics as a pseudo science and only the modern detection technologies demonstrated its existence [I56], and mitogenetic radiation became also known as bio-photons (the TGD based model for bio-photons is discussed in [K49]). Bio-photons form a relatively featureless continuum at visible wavelengths continuing also to UV energies, and are believed to be generated by DNA or at least to couple with DNA. The emission of bio-photons is most intense from biologically active organisms and the irradiation by UV light induces an emission of mitogenetic radiation by a some kind of amplification mechanism. It has been suggested that bio-photons represent some kind of leakage of a coherent light emitted by living matter.

According to Russian researcher V. M. Injushin [I69] , mitochondrios emit red light at wavelengths 620 nm and 680 nm corresponding to energies 2 eV and 1.82 eV. According to the same source, the nucleus of cell sends UV light at wavelengths 190, 280 and 330 nm corresponding to the energies 6.5, 4.4 and 3.8 eV. The interpretation as a kind of leakage of coherent light would conform with the identification in terms of BE condensates of dark photons with $\hbar_s/\hbar \simeq 2^{11}$ emitted at wavelengths varying in the range $.3 - 1.25$ mm and decaying to photons with energies visible and UV range. For instance, 1.82 eV radiation corresponds to a dark photon wave length of 1.4 mm for $v_0(eff) = 2^{-11}$. A bio-control of ordinary bio-matter at sub-cellular level performed by dark matter from the millimeter length scale could be in question. This proposal conforms with the fact that 1 mm defines the scale of the blobs of neurons serving as structural units in cortex.

The analysis of Kirlian photographs has shown that the pattern of visible light emitted by various body parts, for instance ear, code information about other body parts [I100]. These bio-holograms for which a general model is discussed in [K19] could be realized as dark photon laser beams.

In phantom DNA effect [I45] a chamber containing DNA is irradiated with a visible laser light and the DNA generates as a response coherent visible radiation at same wavelength. Strangely enough, the chamber continues to emit weak laser light even after the removal of DNA. This effect could be due to the decay of a dark photon BE condensate remaining in the chamber. Also the findings of Peter Gariaev [I47] about the effects of visible laser light on DNA, in particular the stimulated emission of radio waves in kHz-MHz frequency range might also relate to dark photons somehow.

Part III

SELF-ORGANIZATION IN LIVING MATTER

Chapter 10

Quantum Theory of Self-Organization

10.1 Introduction

Self-organization [B23] seems to be closely related to the generation of fractal patterns and the book of Barnsley [A25] about fractals gives rather convincing arguments supporting the belief that a very general class of fractals can be regarded as fixed points of iteration. The space in which fixed point exists is rather abstract: typically it belongs to the set of subsets of some space, say, 3-dimensional Euclidian space. This fixed point can be a landscape, biosystem, ecological population, hydrodynamical flow,... For instance, the success of this recipe in reproducing even a virtual photo of a forest is amazing. Even evolution could be regarded as resulting from this kind of iterative process leading gradually to a fixed point.

One can even consider the possibility that iteration, if understood in a sufficiently general sense, could be the basic element of self-organization. There is no obvious way how this iteration could result from the equations of the classical physics. For instance, Haken has been ready to consider the possibility that subsystems, even electron, are actually certain kind of computers, cellular automata and that the basic computational step would provide the required fundamental iteration step. Zero energy ontology assigns to electron fundamental time scale of.1 seconds, which is also a fundamental bio-rhythm so that this idea need not be so crazy as it looks first.

TGD suggests that the quantum jump between quantum histories could be the fundamental iteration step in very general sense of the world. This iteration would leave the other boundary of causal diamond to reduced state but change the state at the other boundary and also the average position of the other boundary. Self-organization would have a completely new meaning as the evolution of the hierarchical structures formed by conscious entities - selves. The iteration step could be seen reaction of self to its state created in previous quantum jump involving also the interaction with external world essential for self-organization.

The recent progress in understanding of how experienced time and its arrow emerge in Zero Energy Ontology (ZEO) allows to have a more concrete view about how the iterative aspect of quantum self-organization emerges.

1. State function reduction can occur at the upper or lower boundary of causal diamond CD and can do so repeatedly: this gives rise to a definite arrow of time, which changes when the boundary where reduction takes place, changes.

2. Let us assume that lower boundary to which we assign positive energy part of the state is the boundary where reductions occur. One can write the zero energy state as a superposition of products of positive and negative energy states associated with the two boundaries.

3. As in standard quantum measurement theory, repeated state function reductions to the lower boundary of CD leave the positive energy parts of thestates with same quantum numbers invariant. At opposite boundary the non-triviality of M-matrix means that corresponding part of the state changes and product state is replaced with superposition of products with same positive energy part.

4. Even de-localization in moduli space of CDs with fixed lower boundary can occur: the position of upper tip characterized by the tip-tip proper time distance from lower boundary and discrete Lorentz boost leaving the lower boundary invariant can take place. Dispersion analogous to that for Schrödinger equation takes place, and the average temporal distance between tips increases: this corresponds to the experience about a flow and arrow of time. Self can be identified as the sequence of quantum jumps performing state function reduction at fixed boundary of CD. The state function reductions clearly act like iteration. If repeated sufficiently many times state function reduction can lead to a fixed point or limit cycle and statistical variant of chaos theory can result as outcome.

Quantum jump decomposes to quantum jumps performed by separate selves with self being defined as subsystem able to remain unentangled during sequential quantum jumps. State function reduction part of quantum jump corresponds to the measurement of density matrix for some subsystem of self (or equivalently, for its complement inside self). If each quantum jump involves localization in zero modes representing classical degrees of freedom entangled with quantal degrees of freedom within accuracy defined by the measurement resolution, the final states of quantum jumps are superpositions of macroscopically equivalent space-time surfaces. This would explain the classicality of the world of the subjective experience.

Negentropy Maximization Principle (NMP) states that in a given quantum state only one of the most quantum entangled subsystems can perform the quantum jump. The reduction of the entanglement entropy in the quantum jump is as large as possible: presumably the interpretation of entanglement entropy as some kind of information gain makes sense [K26]. Quantum jumps inside self imply dissipation crucial for self organization and quantum jump could be regarded as the basic step of iteration process. If self consists of a large number of nearly identical sub-selves, quantum statistical determinism implies that quantum jump can be interpreted as iterated map from the point of view of self. From the point of view of entire Universe this is certainly the case. NMP predicts that self organization and hence presumably also fractalization can occur inside selves.

The recent view about quantum TGD involves several incredients which allow to considerably sharpen and enrich the original view about self-organization. In zero energy ontology (ZEO) all space-time sheets are "mind-like" space time sheets assigned with cognition. Number theoretical Shannon entropy having also negative values and making sense for rational or at most algebraic entanglement probabilities allows negentropic entanglement so that Negentropy Maximization Principle (NMP) in this case favors formations of larger coherent structures. One could say that intelligent life resides in the intersection of real and various p-adic worlds much like rationals represent islands of order in the sea of chaos defined by generic real or p-adic numbers. Dark matter hierarchy with levels partially labelled by the value of Planck constant brings in dark matter playing a key role in biological self organization. Consistency of NMP with standard quantum measurement theory allows only entanglement characterize by a density matrix proportional to unit matrix. The entanglement matrix proportional to a unitary matrix associated with quantum computation defines this kind of density matrix.

With respect to geometric time the contents of conscious experiences is naturally determined by the space-time region inside CD in zero energy ontology. This geometro-temporal integration should have subjecto-temporal counterpart. The experiences of self are determined by the mental images assignable to sub-selves (having sub-CDs as embedding space correlates) and the quantum jump sequences associated with sub-selves define a sequence of mental images. The hypothesis is that self experiences these sequences of mental images as a continuous time flow. In absence of mental images self would have experience of "timelessness" in accordance with the reports of practitioners of various spiritual practices. Self would lose consciousness in quantum jump generating entropic entanglement and experience enlightment if the resulting entanglement is negentropic. The assumption that the integration of experiences of self involves a kind of averaging over sub-selves of sub-selves guarantees that the sensory experiences are reliable despite the fact that quantum nondeterminism is involved with each quantum jump.

Thus the measurement of density matrix defined by the $MM^{\dagger}$, where M is the M-matrix between positive and negative energy parts of the zero energy state would correspond to the passive aspects of consciousness such as sensory experiencing. U would represent at the fundamental level volition as a creation of a quantum superposition of possibilities. What follows it would be a selection between them. The choice between different maxima of Kähler function could be basically responsible for the active aspect of consciousness. The fundamental perception-reaction feedback loop of biosystems would result from the combination of the active and passive aspects of consciousness represented by U and M.

TGD indeed gives good hopes for understanding self-organization using quantum level concepts.

1. Quantum criticality of TGD suggests the existence of macroscopic quantum systems in all length scales so that quantum theory of self-organization might apply also in the description of the hydrodynamical self-organization. The proposed interpretation of dark matter in terms of a hierarchy of Planck constants requiring a generalization of the notion of embedding space to a book like structure with pages characterized partially by the value of Planck constant leads to a similar prediction [K40]. On basis of some intriguing findings about planetary orbits the space-time sheets mediating gravitational interaction are proposed to have gigantic values of Planck constant: the mysterious dark energy would corresponds to macroscopic quantum systems in astrophysical and even cosmic length and time scales [K92].

   The recent understanding of quantum criticality leads to a general vision about life as an attempt to stay at quantum criticality (homeostasis) while phase transitions reducing criticality and increasing the value of Planck constants and increasing negentropic resources of the system tend to occur spontaneously. This vision is reminiscent of the vision of Eastern philosophies involving the notions of Karma, ego, and "Let go".

2. Both p-adic length scale hierarchy and hierarchy of Planck constants suggest that evolution can be seen as a dispersion or migration like process in the world of classical worlds whose sectors correspond CDs characterized by the positions of their tips, by the p-adic length scales characterizing the light-like 3-surfaces and also by the sizes of corresponding CDs as well as the page of the Big Book labelled by the value of Planck constant. Since the number of primes larger than given prime is infinite, one expects that p must increase in the long run. This would mean that the p-adic primes characterizing given light-like 3-surfaces tend to increase meaning also the increase of the size of the surface. A possible interpretation is in terms of cosmic expansion. Also NMP favours the increase of p and implies evolution and second law of thermodynamics since maximum entanglement entropy equal to maximum negentropy gain in quantum jump increases with p. The phase transitions increasing the value of Planck constant involve tunnelling between the pages of the book like structure defined by the embedding space, and generate quantum coherent space-time regions with increasing size. They would give rise to similar evolution. A possible interpretation is as a counterpart of quantum counterpart of cosmic evolution reduced to a sequence of phase transitions. These periods would correspond to accelerated cosmic expansion difficult to understand in standard cosmology. The model of EEG would be one concrete application of this vision. An open question is whether the two expansion like evolutions are independent or whether there is some connection between them.

3. The replacement of the point like particle with 3-surface brings in an infinite number of zero modes characterizing the shape and size of and the classical Kähler field (projection of CP_2 Kähler form) associated with the space-time surface $X^4(X^3)$ assignable to a given 3-surface X^3 having components at the boundaries of CD and its sub-CDs. Even macroscopic 3-surfaces behave like elementary particles in these degrees of freedom. These zero modes serve as fundamental order parameters, which in the ordinary theories of self-organization must be introduced in an ad hoc way. As already noticed, localization in the zero modes within measurement resolution implies that the world of conscious experience looks classical and that time evolution in zero modes can be regarded as hopping like motion.

4. Long range quantum correlations are crucial for quantum self-organization. Quantum criticality is indeed basic aspect of quantum TGD. The preferred extremals of Kähler action having interpretation as generalized Bohr orbits are critical in the sense that there exist deformations of the space-time surface -actually infinite number of them- for which the second variation of Kähler action vanishes. The hierarchy of Planck constants implies the criticality against phase transitions changing the value of Planck constant and realized as a tunnelling

between the pages of the "Big Book" [K40]. This has many implications. Quantum criticality is characterized by long range quantum correlations and implies also fractality. The universality of $1/f$ noise, which is a direct consequence of criticality, is difficult to understand in standard physics context since critical systems are by definition unstable. Therefore the universality of $1/f$ noise could be seen as a direct support for quantum criticality of the entire Universe. From the real point of view self itself is a critical phenomenon. The exact vanishing of entanglement with external world is extremely improbable and must be replaced with the vanishing of entanglement modulo finite measurement resolution. If one accepts the notion of number theoretic Shannon entropy, entanglement can be negentropic and instead of a loss of consciousness leads to kind of enlightment experience. Also in this case the criticality is present since entanglement probabilities are not in general rational nor even algebraic.

5. Arbitrarily large join along boundaries condensates of 3-surfaces are possible by quantum criticality and this suggests the possibility of arbitrarily large macroscopic quantum subsystems. Especially interesting biological examples of join along boundaries bonds are chemical bonds, the MAPs connecting microtubules and gap junctions connecting cells. Join along boundaries bonds can also join mind-like space-time sheets.

6. The many-sheeted space-time concept having hierarchical structure provides the realization of a fundamental slaving hierarchy at the level of the space-time geometry. p-Adic length scale hierarchy and the hierarchy of Planck constant make this hypothesis quantitative.

7. Spin glass analogy leads to an infinite-dimensional generalization of Thom's catastrophe theory and the maxima of Kähler function play the role of the minima of the potential function in Haken's theory of self-organization. Vacuum functional of TGD in turn is in the role of the generalized partition function appearing in Haken's theory.

8. Dissipation can be understood as caused by quantum jumps and occurs only inside selves. Dissipation leads to Darwinian selection of the asymptotic self-organization patterns and the selection of both genes and memes, in particular stable mental images, can be understood as resulting from quantum self-organization. Note that dissipation can be regarded as a direct signature of consciousness.

The quantum version of Haken's theory of self-organization is proposed. Spin glass analogy means that "energy" landscape has fractal valleys inside valleys structure: this structure is important for understanding long term memories. A crucially important aspect of the quantum self-organization is the Darwinian selection of very few asymptotic self-organization pattterns by dissipation which explains the selection of both genes and memes: this selection provides royal road to the understanding of various miraculous feats performed by living matter.

In ZEO self-organization takes place for 4-D spatio-temporal patterns since 3-surfaces are pairs of space-like surfaces at the boundaries of CD and maxima of Kähler function are selected in the process. This brings in totally new and highly non-trivial aspect. These temporal patterns correspond to behaviors and functions in living matter. One could understand complex miracle the generation of complex spatio-temporal patterns such as morphogenesis as a sequence of 4-D trials. In this framework evolution in given time scale is not an outcome of random choice followed by selection as Darwinian dogma states.

Rupert Sheldrake [I88] postulates the concept of morphic fields and morphic resonance making possible learning and memory at the level of species. The comparison with Rupert Sheldrake's concepts of morphic field and morphic resonance leads to interesting ideas about how learning at the level of species could occur quantum-mechanically. For instance, the phenomenon of biofeedback suggests that self could quite generally effectively act on its sub-selves. In zero energy ontology all quantum states have properties allowing to interpret them as memes or quanta of morphic fields and the challenge is to find their biological counterparts. DNA as topological quantum computer hypothesis suggest the identification of the biological memes as topological quantum computer programs assignable to the intronic portion of the genome and coded also by nerve pulse patterns. The notion of magnetic body as intentional agent leads to a concrete model for the morphic resonance as a transfer of topological quantum computation programs between separate brains with the mediation of the personal magnetic bodies and the magnetic body of Mother Gaia using EEG like communications. The recent view is that magnetic bodies in 4-D sense are the TGD counterparts of morphic fields serving as templetes for the self-organization of ordinary matter. The model explains also "alike likes alike" rule.

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` [L13].

10.2 Quantum Theory Of Self-Organization

In the following basic ideas about self-organization and its quantum counterpart are introduced.

10.2.1 Basic Characteristics Of Self-Organization

Self organizing system corresponds typically to a system dissipating the energy fed into it. Dissipation leads to typical self-organization patterns decomposing into more or less autonomous subsystems. Subsystems perceive the state of the external world and reacts to it. Human society is a typical example in which individuals or groups of them perceive and react. Self-organization is also critical phenomenon in the sense that new self-organization patterns are formed in phase transition like manner at the critical values of the parameters characterizing the interaction of the system with external world. Co-operatitivity, long range correlations and fractality, typical characteristics of critical phenomena, are involved with the emergence of new self-organization patterns. Also spontaneous symmetry breaking associated with the phase transitions changing self-organization pattern is a characteristic of self-organization process.

Iteration, understood in a very general sense, seems to be the basic element of self-organization. A good example is provided by cellular automata (game of life is the best known example). Automaton consists of cells, which perceive their surroundings and perform a decision to change their state according to some rule. Rule need not be deterministic but the dynamics dictated by it is irreversible. This is what makes it so difficult to understand how iteration might result from the reversible equations of physics and suggests that thermodynamics or some deeper principle behind thermodynamics is important.

Second example is camera, which monitors tv screen to which the picture taken by the camera is the feedback. This system exhibits typical self-organization patterns obtained by varying the direction angle of the camera with respect to the TV screen. Iteration is rather abstract process now: camera perceives the state of tv and reacts by sending a new picture to the TV screen.

Benard convection is a third standard example of self-organization. When liquid is heated evenly from below, a temperature gradient develops and at some critical value of temperature gradient, convection sets on. A flow pattern consisting of liquid cells is formed. The size and shape of cell as well as the pattern of liquid motion in cell depends on the parameters characterizing the situation (size and shape of the liquid vessel, the temperature difference, ...). As temperature difference increases, more complicated flow patterns emerge: what happens is essentially that patterns of larger scale coherent motions emerge by the organization of the Benard cells to larger units.

Biosystems provide more complicated examples of self-organization. In this case self-organization has many hierarchical levels. First DNA and proteins together with genetic code are formed by self-organization at molecular level, then come monocellulars, multicellulars, ..., individuals, families, social organizations, ... Clearly, subsystems of previous level form combine to form larger coherent subsystems at the higher levels of self-organization. Here the basic interaction step is response to a response.

Iteration is clearly a "social" process: subsystem perceives consciously the external world and reacts to it. Subsystem can in principle be any subsystem of the entire system so that the scenario is considerably more general than cellular automaton. The process can also create a subsystem such as Benard cell in Benard convection or a cell in biological evolution.

10.2.2 Self-Organization As Organization Of Self-Hierarchies

TGD suggests that the quantum jump between quantum histories could be the fundamental iteration step of self-organinization with M-matrix related to the perception and U-process to the volitional act resulting as a reaction to the perception. Even more, self-organization has a completely new meaning in TGD. Self-organization can be identified as the evolution of hierarchical structures formed by conscious selves. Zero energy ontology, p-adic length scale hierarchy, and the hierarchy of Planck constants bring in additional refinements to the picture.

Quantum jump as the basic iterative step of self-organization

In TGD subjective time evolution corresponds to the sequence of quantum jumps

$$\Psi_i \rightarrow U\Psi_i \rightarrow \Psi_f \quad ,$$

where U represents unitary quantum mechanical "time evolution".

Quantum jump corresponds to the measurement of density matrix for some subsystem of self (or equivalently, for its complement inside self). In quantum jump a localization in zero modes (possibly modulo measurement resolution) takes place and the final states of quantum jumps are superpositions of space-time surfaces indistinguishable in the measurement resolution used This would explain the classicality of the world of the subjective experience. Quantum jump occurs also between two classical histories, say between solutions of reversible equations of hydrodynamics in Benard convection.

In zero energy ontology the view about quantum state as quantum history finds a more precise quantitative characterization through the notion causal diamond (CD).

Autonomous subsystems of self-organized system as selves

A crucial concept is that of self being defined as a subsystem able to remain unentangled during sequential quantum jumps. Self would lose consciousness when it entangles. What this statement really means is far from obvious and I have proposed several interpretations.

1. The idea that even slightest entanglement leads to a loss of consciousness does not sound realistic. This suggests that entanglement should be defined only modulo finite measurement resolution. System would be conscious only provided that its entanglement entropy with the external world is below the value defined by the measurement resolution. For hyper-finite factors of type II_1 the notion of finite measurement resolution is unavoidable. The concrete interpretation at space-time level would be that space-time sheets (sub-selves) topologically condensed at larger space-time sheets (selves) can be connected by flux tubes to form an entangled state. The selves represented by the larger space-time sheets would remain unentangled in the resolution applying to the systems themselves (flux tubes would be invisible in this resolution). This invisible entanglement would however give rise to a sharing and fusion of mental images implying what might be called stereo consciousness.

2. How the notion measurement resolution should be defined is far from obvious. p-Adication approach suggests that finite measurement resolution boils down to a pinary cutoff for the p-adic entanglement entropy represented as a series in powers of p. This pinary cutoff should have also space-time correlate. For hyper-finite factors of type II_1 and type III_1 emerging naturally in quantum TGD entanglement entropy is always defined only modulo finite measurement resolution, which can be characterized in terms of inclusions of hyper-finite factors [K118]. The included factor defines the measurement resolution in the sense that its action creates states not distinguishable from the original in the resolution used. There should exist a connection between the two approaches.

3. A further complication is due to the fact that also the p-adic variants of Shannon entropy obtained by replacing the logarithm of probability with the logarithm of the p-adic norm of probability make sense if entanglement probabilities are rational or have values in some algebraic extension of rationals. The fact that number theoretic entanglement entropy can be negative it especially attractive from the point of view of consciousness theory and also

quantum computation since entanglement indeed carries information. There is also a temptation to identify evolution as the emergence of increasingly complex systems having negative entanglement entropy. The generation of negative entanglement entropy could correspond to a kind of enlightenment experience-fusion to a sea of consciousness- instead of a loss of consciousness.

4. This forces to reconsider the original vision that everything is conscious but consciousness can be lost as the system entangles in U process. U process generates highly entangled states and the sub-sequent state function reduction (possibly modulo measurement resolution) repeatedly decomposes the Universe (or CD) into unentangled pairs of subsystems. The process stops for any subsystem for which all subsystem pairs have either bound state entanglement or negentropic entanglement (see **Fig.** `http://tgdtheory.fi/appfigures/cat.jpg` or **Fig. ??** in the appendix of this book). If the bound state entanglement is entropic, the entangled subsystems lose consciousness. If the entanglement beween the subsystems in negentropic the process stops but subsystems remain conscious. Mystics might associate the entropic entanglement to what they calls attachment and negentropic entanglement to a relationship which they might characterize as love.

5. Zero energy ontology brings in additional aspects. Zero energy states correspond to entangled pairs of positive and negative energy states located at the opposite light-like boundaries of a given causal diamond (CD) defined as the intersection of future and past directed light-cones. Strictly speaking a Cartesian product of CD with CP_2 is in question. CDs form a fractal hierarchy. In the ordinary ontology zero energy state corresponds to a physical event. The time-like entanglement between positive and negative energy states defines M-matrix generalizing the notion of S-matrix. Time-like entanglement must be fundamental also from the point of view of consciousness as a reduction of quantum state to a state with well defined values of observables for the initial (positive energy) and final (negative energy) states.

The identification of the space-time correlates of selves is not so obvious as one might think. One can imagine three options. The space-time correlates of selves are space-time sheets or CDs or somehow combinations of these two.

1. If space-time sheets serve as correlates for selves, the space-time correlate for the entanglement is the presence of flux tubes connecting the space-time sheets serving as correlates for selves. The entanglement which corresponds to join along boundaries bonds associated with sub-selves (smaller space-time sheets topologically condensed at the space-time sheet representing self) is below the measurement resolution assignable to self. In this kind of situation selves remain conscious whereas sub-selves loose consciousness for positive entanglement entropy and fuse to form single stereo mental image of self. For negative entanglement entropy sub-selves would remain conscious.

2. In zero energy ontology [K29] one is forced to ask whether the notion of self should be defined at the level of embedding space rather that at the level of space-time sheets so that a given CD would serve as a correlate for self. This identification leads to a beautiful argument for how the arrow of subjective time, the flow of subjective time, and the localization of the contents of conscious experience around a narrow time interval takes place [K10]. There is no reason for why CDs should not be allowed to overlap and this overlap would be a natural correlate for the sharing and fusion of mental images. Both of these identifications look natural and one can argue that the geometric correlates of self exist at both embedding space and space-time level.

3. If both space-time sheets and CDs serve as correlates for selves, the join along boundaries bonds would connect space-time sheets associated with the two CDs and would belong to their intersection. One can also require that the CDs are at the same p-adic level of hierarchy. In other words, CDs correspond to the same value of p-adic prime near a power of two meaning that the temporal distance between the tips of CDs is same octave of CP_2 time for the standard value of Planck constant. The hierarchy of Planck constants [K40] means an additional complication in this picture but does not bring in anything essentially new.

One should also understand how the experience about the flow of subjective time emerges.

1. It seems obvious that quantum jumps must somehow integrate to self: quantum jump would be the elementary particle of consciousness and self the many particle state -possibly bound state (one can of course wonder what the notion of bound state means in case of zero energy states: can one say that positive and negative energy parts of the state form a bound state?) This analogy and the identification of zero energy states as events suggests that the notion of self could be reduced to that of quantum jumps so that self hierarchy would correspond to a hierarchy of quantum jumps within quantum jumps and also to the hierarchy of CDs within CDs.

2. The state function for the zero energy state should create the fundamental experience about time flow. The value of the time increment associated with the quantum jump would be determined by the temporal distance between the tips of CD and determine the interval about which the contents of consciousness is about. Note that for quantum states identified as time equal to constant snapshots quantum jump cannot give rise to an experience about flow of time since information about two values of geometric time is not present. Before zero energy ontology the proposed way out of this problem was the failure of classical determinism in the standard sense and zero energy ontology could be seen as a way to formalize this failure.

3. The fractality of zero energy ontology implies that zero energy states are analogous to self-organization patterns and that a sequence of quantum jumps leads to an asymptotic self-organization pattern in 4-D sense. The M-matrix defining the generalization of S-matrix is indeed a "complex square root" of the density matrix so that statistical and thermodynamical aspects are present already at the fundamental level.

Since self behaves effectively like a separate autonomous universe, an attractive hypothesis is that the typical decomposition of self-organized system to almost autonomous subsystems corresponds to the decomposition of universe to selves. This means very close connection between self-organization theory and theory of consciousness.

1. The hierarchy of selves corresponds geometrically to the hierarchies of space-time sheets and CDs and defines obvious counterpart for the nested slaving hierarchies of self-organized systems with the property that the system at given level of hierarchy serves as a master for the lower level systems inside it. Zero energy ontology implies that physical state itself corresponds to a physical event is more like a process than state so that self-organization is basically evolution of temporal rather than spatial patterns. In neuroscience this has dramatic implications for the model of long term memories and also for the models of sensory perception and motor action.

2. Although active quantum jump itself is nondeterministic, quantum statistical determinism implies that the time evolution by quantum jumps is predictable at the limit of large self having large number of sub-selves. In this quantum evolution is a genuinely iterative process in the space of distribution functions for various types of selves with interaction step defined by state function reduction for zero energy state (perception) following by the volitional act representing the reaction creating a superposition of possibilities (U-process). At the level of the large sub-selves there is always non-predictability involved. This feature could make it possible to understand the special features of biological self-organization. A good example is the behavior of group of people who meet for the first time: self-organization leads rapidly to an adoption of simple social roles. In this kind of self organization both active and passive quantum jumps play important role.

3. If the notion of number theoretic entropies is accepted, the generation of larger quantum coherent structures by the generation of rational or algebraic entanglement is favored by NMP. This feature distinguishes quantum TGD from other quantum theoretic approaches to self-organization and could allow to understand the miracle like phenomena occurring in the evolution of the living matter. One can ask whether this process is always involved in the phase transitions generating larger coherent structures (also the increase of Planck constant and p-adic length scale could be involved).

10.2.3 Dissipation And Quantum Jumps Between Histories Concept

The phenomenon of dissipation is paradoxical from the point of view of standard physics. It is generally accepted that fundamental laws of physics are reversible but everyday reality is manifestly irreversible. Thus the situation is rather schizophrenic. Two worlds, the reversible and extremely beautiful world of fundamental physics and the irreversible and mathematically rather ugly "real" world, seem to exist simultaneously. The description of dissipation is highly phenomenological: one introduces mathematical monsters like non-Hermitian Hamiltonians; in particle physics particle decay widths are introduced by making energies complex; in macroscopic length scales one introduces parameters like friction coefficients, viscosity, diffusion constants, etc.. The mathematical beauty of the reversible world is lost and dissipation becomes an unavoidable nuisance of physics, which perhaps explains why so little conscious thought is devoted in the attempts to understand why these two worlds seem to co-exist.

This schizophrenic world picture is of course logically inconsistent. Something in the implicit assumptions underlying this paradoxical world view must be wrong. Quantum jump between quantum histories concept indeed resolves the paradox and explains the apparent existence of two worlds as resulting from a wrong view about psychological time. Without quantum jumps there would be single reversible reality behaving determistically and there would be neither dissipation nor consciousness. Quantum jumps between the reversible realities however cause dissipation, which can be more correctly seen as a self organization via quantum jumps and as a necessary prerequisite for evolution and consciousness. The source of all the ugly mathematics related to the description of dissipation is the failure to realize that there are two time developments: subjective time development proceeding via quantum jumps and geometric time development described by the dynamical equations without dissipation. The ugly dissipative terms in dynamical equations result, when the sequence of quantum jumps between time developments is replaced with single dissipative time development. One can very loosely say that the dissipative world is envelope for the classical worlds, one classical world per CP_2 time. Or more concretely, dissipative space-time surface is the space-time surface going through a sequence of 3-surfaces defined by the values of psychological time measured using CP_2 time as unit.

Dissipation can be seen as a phenomenological description for the tendency of the self-organizing development by quantum jumps to lead to fixed points, limit cycles, limiting tori, strange attractors, etc.. in the space of quantum histories. In this description irreversible time development is "almost" envelope for the family of reversible time developments defined by quantum jumps: various parameters characterizing dissipation describe the deviation from the exact "envelopeness". Hence the study of chaotic dissipative systems could be also seen as a study of the phenomenological descriptions for the asymptotic behaviors yielded by the time development by quantum jumps. It is not of course clear whether this kind of effective description really works always or whether one should replace it by a genuine quantum description under some circumstances.

Consider as an example the description of a self organizing system using Haken's theory of self-organization relying on the hypothesis that system's states correspond to the minima of free energy function. Free energy depends on external parameters. When the value of some external parameter becomes critical, large fluctuations in long length scales occur and new level of self-organization with new length scale emerges or disappears in a phase transition like manner. For instance, potential well can split into two potential wells and system selects either well. This suggests that near the critical values of the external parameters quantum statistical determinism and hence also effective description fails at macroscopic length scales. The catastrophic changes in system's behavior could correspond to macroscopic quantum jumps. Biosystems obviously provide excellent candidates for critical systems. Since TGD Universe is quantum critical, any subsystem is basically critical system: only the time scale of the critical fluctuations determines whether given system looks critical from human point of view. In particular, selves are critical systems since the increase of the real entanglement above critical value means disappearance of self. Since time development corresponds to hopping in zero modes which are the fundamental order parameters in TGD framework, the picture of Haken applies almost as such as far as development in zero modes is considered. An interesting question is whether the criticality in zero modes actually corresponds to criticality for the disappearance or occurrence of new self.

Dissipation can be seen as an extremely concrete proof for the hypothesis that quantum jumps between quantum histories occur all the time. However, to possibly convince colleagues about this, very delicate experiments must be invented (say tribar effect testing the new concept of psychological time described in [K58] ! The crucial demonstration is however at the level of mere logic: 0 and 1 are the numbers needed, no experiments testing 10: th decimal for some quantitative prediction are needed.

Dissipation can be seen also as direct signature for consciousness and existence of selves Any system, which has ability to dissipate, to grow older, must have moments of consciousness in some length scales. Living systems are not the only systems growing old. Buildings and cars and computers grow old. Hydrodynamic flow without external energy fed gets older by gradually losing its velocity- (and Z^0 magnetic-) vortices. The rate of the energy loss by dissipation could be even seen as a rough measure for the level of consciousness.

The crucial question is however in which length scales quantum jumps occur: does all the dissipation occur in atomic length scales as standard physics strongly suggests or are all length scales involved as quantum criticality of TGD and new TGD based space-time concept suggest. Hydrodynamic flow is especially interesting example in this respect. The TGD based model for turbulent flow [K51]. with external energy feed assumes that dissipation occurs in all length scales: the decay of vortices of given radius to smaller vortices should therefore involve primitive consciousness in the length scale of the vortices. In turbulent flow with external energy feed there is stationary energy flow between space-time sheets of various sizes and this means that the level of consciousness, if indeed measured by energy dissipation, is same at various p-adic length scales involved. In this picture life as we know it, is a result of continual quantum self-organization of the sea water: indeed, we are 70 per cent of sea water.

One can represent an objection against above line of reasoning. The dissipative parameters of classical dynamics certainly make it ugly but this description is very practical. Should one really give it up at the fundamental level? This need not be the case. The above argument mentions nothing about quantum classical correspondence, which in its strongest from requires that also quantum jumps sequences and therefore also dissipation should have space-time correlates. The failure of the classical determinism in the standard sense of the word for Kähler action caused by its immense vacuum degeneracy forces to replace space-like 3-surfaces with unions of space-like 3-surfaces with time-like separations so that there are good reasons to hope that these space-time correlates exist. In this framework zero energy ontology based on the notion of causal diamond is very natural. In zero energy ontology unitary S-matrix is replaced by a "complex square root" of the density matrix decomposing to a product of diagonal density matrix and unitary S-matrix and defining the time-like entanglement coefficients between the positive and negative energy parts of the zero energy state. Therefore thermodynamics becomes a part of quantum theory. Quantum classical correspondence in turn requires t that thermodynamical parameters have space-time correlates so that the ugly formulation of the dissipative dynamics at space-time level might allow a replacement by something more elegant. This seems to be possible.

The quantum numbers characterizing zero energy states couple directly to space-time geometry via the measurement interaction terms in Kähler action expressing the equality of classical conserved charges in Cartan algebra with their quantal counterparts for space-time surfaces in quantum superposition. This makes sense if classical charges parametrize zero modes. The localization in zero modes in state function reduction would be the WCW counterpart of state function collapse. Thermodynamics would naturally couple to the space-time geometry via the thermodynamical or quantum averages of the quantum numbers.

10.2.4 Co-Operativity, Long Range Correlations, Zero Modes And Quantum Entanglement

The generation of the long range order is one of the basic characteristics of the self-organized systems (the formation of Benard cells in Benard convection, the formation of Taylor's vortex belts in the rotation of a cylinder containing fluid, concentration patterns in Belounow-Zabotinsky reaction). In Benard convection the long range order corresponds to the formation of the Benard cells, whose size and shape depend on the temperature difference and the size and the shape of the vessel. In TGD Universe long range order can be generated in two ways.

The generation of long range order seems to be in contradiction with the fact that the increase of the energy feed should destroy macroscopic quantum bound states. For instance, in the case of Benard convection one could ask why one should not regard the stationary initial state as the state with maximal long range order. A possible way out of the dilemma is the fractal structure of the spin glass energy landscape. The external energy feed drives the system from the bottom of the energy valley which corresponds to a product of uncorrelated valleys, and it sooner or later ends down to the bottom of a deeper energy valley corresponding to a more stable state for which there are long range correlations between the degrees of freedom associated with the values of the initial valleys.

Entropic quantum entanglement between two selves destroys them as separate selves and creates higher level self, which behaves like single system. In the case of negentropic entanglements selves do not lose consciousness but its expansion. At the level of conscious experience this means a formation of a "whole" form its parts. An interesting question relates to the importance of quantum entanglement in self-organization and how closely it corresponds to the formation of long range correlations. "Ontogeny recapitulates phylogeny" metaphor suggests that quantum entanglement is geometrically realized as the formation of flux tube and this would suggest that generation of quantum entanglement requires a direct contact interaction in four-dimensional sense (particle exchange for Feynman graphs). In biosystems the quantum entanglement between cells could be generated during the replication of cell or via the mediation of magnetic flux tubes which are in key role in the model of DNA as topological quantum computer [K5]. For instance, in Benard convection heating could lead to decay of fluid particles and create quantum entanglement between the degrees of freedom associated with distant fluid particles. Also the formation of join along boundaries/flux tube condensates of large size (recall quantum criticality) could be involved in the formation of hydrodynamical quantum entanglement.

Zero modes are the fundamental order parameters in TGD framework.

1. Zero modes characterize the size, the shape, and the classical Kähler field of the space-time surface, and are purely classical variables in the sense that a complete localization for them is in principle possible in each quantum jump.

2. It is not quite clear to me whether the non-existence of metric based volume element in zero modes forces the wave functions in zero modes to have a discrete locus. There certainly exists a symplectic measure defined by the symplectic form in zero modes. It does not however allow a complexification to Kähler form as it does in quantum fluctuating degrees of freedom. This symplectic from could define a hierarchy of integration measures coming as restrictions of $J \wedge J ... \wedge J$ with n factors to $2n$-dimensional sub-manifolds. Under some additional conditions- maybe the homological non-triviality of J and the orientability of the sub-manifold are enough, this measure would define a positive definite inner product and one would have a hierarchy finite-dimensional sub-spaces of zero modes. The maxima of Kähler function with respect to zero modes replace naturally the continuum with a discrete set of points and define the counterpart of the spin glass energy landscape consisting of the minima of free energy. Effective finite-dimensionality and even effective discreteness would be achieved.

3. Zero modes give rise to long range correlations in purely classical sense. This means that even macroscopic 3-surfaces can behave like elementary particles in zero modes: tornado is a good example of a locally chaotic particle like object.

Neural plasticity can be regarded as a self-organization. Sperry observed that when one splits the optical nerve of a frog, the nerve ends fuse again and frog begins to see [B8]. It seemed obvious that nerve ends recombine randomly and a genuine self-organization was in question. This hypothesis can be tested by rotating the eye of the frog by 180 degrees and looking what happens. If frog begins to see normally, genuine neural plasticity and self-organization is in question. If the field of vision is reverted then self-organization is not in question and nerve ends must somehow recognize each other, perhaps chemically. It was found that the frog begins to see things upside-down! A bad blow for self-organization paradigm at that time! Later it was however found that neural plasticity is a real self-organization phenomenon.

An interesting possibility (having at least entertainment value) to explain the disappointing result about frog's eye without losing the faith to self-organization in this particular case. Quantum entanglement might correlate the ends of the split nerve to form single coherent unit and to find each other after splitting. Biotelepathy would be in question. If this were the case, the paradoxical results of these experiments could be regarded as a direct support for biosystems as macroscopic quantum systems. In the same spirit one could also consider the possibility that the fundamental reason for why replication (and also pairing) occurs in biosystems is that replication and pairing creates quantum entangled systems just like the annihilation of photon creates quantum entangled pair of charged particles. In fact, it has turned out that the most elegant model for brain functioning results when one assumes that primary sensory qualia are experienced at a sub-cortical level, presumably at the level of the sensory organs. Quantum entanglement between brain and sensory organs and the TGD based view about long term memory allow to circumvent various objections against this view.

The model for DNA as topological quantum computer relies on the assumption DNA and lipids of nuclear and cell membranes are connected by magnetic flux tubes carrying dark matter. These magnetic flux tubes would appear quite generally and explain the miraculous looking phenomena like bio-catalysis, DNA replication, translation, and transcription based on the ability of biomolecules to find each other in a dense soup of bio-molecules. The basic mechanism would be the contraction *resp.* expansion of the flux tube induced by the reduction *resp.* increase of Planck constant. The phase transitions of gel phase would be based on this process and on the reconnection of magnetic flux tubes changing the topology of the web formed by the flux tubes.

10.2.5 Self Organization Requires External Energy Feed

Essential for the self-organization is external energy feed (Benard convection and even the general intuition about biosystems as systems living in the boundary between chaos and order). This can be understood on basis of Negentropy Maximization Principle [K59]. Only bound state entanglement is stable against the self measurement cascade giving rise to a state preparation during quantum jump. When the system is subject to energy feed the bound states formed by the fused sub-selves decay and thus the number of selves increases and the system become more complex. Each self defines a self-organization pattern. At the level of very large energy feed system becomes chaotic.

The same principle applies in the case of brain and the level of metabolism determines whether brain is in a deep meditative state empty of mental images or in a chaotic state of high arousal. In [K89] a model of cognition based on the generation of hierarchical self cascades is proposed. Metabolism gives rise to the energy feed generating sub-selves. During meditation the energy feed is minimal and sub-selves bound state entangle to for very few sub-selves and a state of "one-ness" results. The fusion gives rise to a stereo consciousness (analogous to stereo vision resulting when left and right visual fields fuse).

In zero energy ontology zero energy state is quantum superposition over states with different energies of the positive energy state. Also super-position of states having different fermion numbers for positive energy state is possible as in case of coherent state of Cooper pairs. Thermal equilibria define square roots of special kind of zero energy states. In this framework the energy feed to the system means that the quantum superposition changes in such a way that the average energy of the positive energy state increases. This excites new degrees of freedom and makes the system more complex. The dissipation caused by quantum jumps reducing entanglement entropy tends to reduce the average energy and this tendency is compensated by the energy feed selecting also the most stable self-organization pattern as a flow equilibrium.

10.2.6 Many-Sheeted Space-Time Concept And Self-Organization

TGD replaces ordinary space-time concept with a hierarchical structure of space-time sheets. For instance, in a proper TGD based description of Benard convection, there is hydrodynamics at each space-time sheet. The sheets of 3-space, which can be regarded basic units of flow (say vortices) at a given p-adic length scale appear as particles at larger space-time sheets. Space-time sheets form in a natural manner master-slave hierarchy: we must in general adopt our behavior to the slow dynamics of external world. This picture has counterpart at the level of CDs.

The original formulation of quantum TGD led to the conclusion that there are two kinds of space-time sheets: material space-time sheets and mind-like space-time sheets so that one can say that Matter Mind duality is realized in geometrical sense: of course, Mind is understood in the sense of cognitive representations only. What one means with mind like space sheets is however not at all obvious.

1. The original proposal was that mind like space-time sheets have a finite temporal extension. In zero energy ontology this holds true for all space-time sheets so that all space-time sheets are mind-like if this criterion makes sense. This could make perfect sense. For instance, the fermionic part of zero energy state can be regarded as a logical rule $A \to B$ with the instances of A and B represented as positive and negative energy fermion states in Fock basis: the Fock basis for many-fermion states indeed defines a representation of Boolean logic.

2. Mind like space-time sheets could be also interpreted as p-adic space-time sheets responsible for cognition whereas real space-time sheets would be matter like in the sense that they define the space-time correlates of sensory experience. The intersection of p-adic and real worlds is along rational and common algebraic points of the embedding space and is discrete (note that this statement assumes the identification of preferred embedding space coordinates). p-Adic space-time sheets could serve as natural correlates of cognition and intentionality and their interaction with real space-time sheets could give rise to effective p-adic topology crucial for the interpretation of p-adic mass calculations. p-Adic space-time sheets have infinite size in real topology so that cognition and intentionality could not be localized in brain. Only the cognitive representations defined by the intersections of real and p-adic space-time sheets allow this localization.

3. p-Adic space-time sheets can be mapped to real space-time sheets via a generalization of the canonical identification map which is continuous and maps rationals m/n, $m, n < p^k$, $k > 0$. to rationals. The explicit form of the map is $m/n \to I_k(m)/I_k(n)$, with $I_k(m)$ defined as

$$x = \sum x_n p^{nk} \to \sum x_n p^{-nk} \quad .$$

   This map could define the effective p-adic topology for real space-time sheets in finite measurement resolution reducing to discretized real topology above distances defined by the p-adic length scale corresponding to p^k. Below the resolution length scale the impossibility to well-order p-adic numbers would correspond to the impossibility to order space-time points by physical measurements. What makes this map attractive is that it commutes with the discrete counterparts of various space-time symmetries in the resolution defined by p^k and is also continuous.

NMP tells that the subsystem with maximum quantum entanglement can perform quantum jump and in this quantum jump previous flow is replaced with a new one. In positive energy ontology one could argue that hydrodynamical equations alone can *never* give rise to the self-organized pattern of the Benard flow as asymptotic solution. In zero energy ontology relying on the failure of standard form of the classical determinism one can imagine the possibility that also the sequence of quantum jumps representing the self-organization process leading to the final pattern has space-time surface as a representative. The space-time sheets associated with the temporal sequences of sub-CDs could represent various steps in the self-organization process whereas the CD itself would represent the outcome of self-organization but in longer length and time scale (the sizes of CDs would come as powers of two). Larger CD could also code the asymptotic self-organization pattern in terms of external parameters such as energy feed dictating it and represented as long range classical fields.

TGD suggests a model of nerve pulse and EEG based on Josephson junction defined by cell membrane. More generally, the hierarchical structures formed by weakly coupled super conductors of various types seem to provide a very elegant general realization of conscious quantum control. Josephson junction networks are known to be self-organizing systems. The coherent light created by linear bio-structures, such as microtubules and possibly also DNA, is also a school example of self-organization [B23]. A gradual generation of phase coherence could in this case make possible the coherent oscillations of entanglement making possible self-organizing quantum jumps.

10.2.7 Infinite Primes And Self-Organization

p-Adic length scale hypothesis stating that the typical size of 3-surface is of order $L_p \simeq l\sqrt{p}$, l about CP_2 size, suggests that the p-adic prime associated with the 3-surface representing entire infinite universe is infinite. The construction of infinite primes [K47] suggests that the decomposition of infinite primes to finite primes corresponds to the decomposition of space-time surface or at least light-like 3-surfaces to regions obeying effective p-adic topology characterized by an finite prime.

This would mean that the effective p-adic topology in a particular sector of WCW corresponds to infinite prime P coding in very well defined sense the decomposition of $X^4(Y^3)$ to p-adic regions obeying finite-p p-adic topology and also providing the effective topology of $X^4(Y^3)$ in asymptotic regions of it: this would explain the success of physics based on real numbers.

The often stated intuitive belief is that real topology corresponds to the limit of p-adic topology as p approaches infinity. I must admit that I have not really understood this statement although it certainly makes sense if one considers solutions of polynomial equations with integer coefficients interpreted as equations in p-adic number field. In any case, this raises the question whether infinite primes could define p-adic topologies as such in the same manner as finite primes do. One can also consider the formulation of perturbation theory in powers of infinite prime p and thus containing only two non-vanishing orders. If one modifies the canonical identification to $I_k(m/n) = I_k(m)/I_k(n)$ defined previously, finite rationals are mapped to themselves already for $k = 1$ and infinite-p p-adic topology is more or less equivalent with the restriction of the real topology in the field of rationals.

Infinite-p p-adic space-time surfaces and real space-time surfaces would have rational points of embedding space in common and the topology would be the same real topology in the set of rational points. This applies also at the level of WCW where point corresponds to 3-D light-like 3-surfaces. The number theoretic anatomy of the infinite prime would however code for the p-adic effective topologies of the light-like 3-surfaces characterizing the space-time surface via quantum holography: this decomposition corresponds to the structure of a particular point of the world of classical worlds.

There is entire hierarchy of infinite primes and infinite prime in general decomposes to infinite primes belonging to the lower level of infinity and at the bottom of this decompositional hierarchy are finite primes.

1. Infinite primes form a hierarchy such that infinite primes p_N at level N decompose in a well defined manner to infinite primes p_{N-1} at level $N-1$, which in turn.... decompose into infinite primes at the lowest level, which in turn decompose into finite primes.

2. The infinite primes of level $N-1$ label single boson and single fermion states of a supersymmetric theory. Therefore each infinite prime at level N corresponds formally to a many-particle state consisting of bosons and fermions. Those primes of level $N-1$ for which fermionic or bosonic occupation number are non-vanishing, define the entire system. "Ontology recapitulates phylogeny" metaphor suggests that the occupied infinite primes correspond to space-time regions appearing in the decomposition of the space-time surface to regions with different effective p-adic topologies. Thus the effective topology of D_P and the spectrum of p-adic topologies for the space-time surfaces in D_P correspond to each other in one-to-one manner.

3. The occupied fermion states of level $N-1$ are analogous to a subsystem of the many-particle state formed by fermions and bosons. By b), this subsystem corresponds to a union of p-adic regions of the entire space-time surface. A very tempting identification of this region is as the sub-universe to which NMP applies in the quantum jump. The sub-system of this sub-universe winning negentropy gain maximization race makes the quantum jump.

4. Actually space-time sheets identified in this manner form an entire hierarchy since similar decomposition occurs for each infinite prime at level $N-1$. The lowest level corresponds to infinite primes having decomposition to finite primes.

p-Adic evolution means that the infinite prime associated with the space-time surfaces appearing in final states of quantum jump increases in the long run. The increase of the p-adic primes associated with finite space-time regions in the long run and implies also the increase of infinite prime. This means that evolution at global level is implied by local evolution.

10.2.8 Illness As A Failure To Self-Organize Properly

One can consider two definitions of illness.

1. Structural illness: Illness as a loss of quantum coherence at some level. For instance, some group of neurons fails to form a quantum coherent system.

2. Functional illness: Illness as the failure to self organize effectively. For instance, cancer cells fail to organize to larger coherent units and behave in a selfish manner. Here Negentropy Maximization Principle relying on number theoretic variants of Shannon entropy suggests a way to understand illness.

Actually, 1) might reduce to 2) since biosystems are not static systems but more like vortices in a stream with fluid particles being replaced with new ones all the time: self-organization creates various subsystems again and again. In zero energy ontology the equivalence of the two definitions would be even more natural.

It seems indeed possible to understand the illness qualitatively in TGD based theory of self-organization. In TGD framework one can envision living system as a dynamical hierarchy of selves. For instance, cognitive acts corresponds to self cascades, our thoughts correspond to sub-selves as also do various components of sensory experience. In this picture illness is pathology resulting from the inability of some sub-selves to remain conscious so that higher level self are not able to form mental images crucial for the survival. Some subsystems lose consciousness, and the system could be said to be ill.

The mathematical correlate for the loss of consciousness would be entropic entanglement with the external world. Subsystem can remain conscious by keeping the entanglement entropy below the maximum value defined by the measurement resolution or by generating negentropic entanglement. A superposition of states with both negentropic and entropic entanglement is generated in U-process and the subsequent process involves many selections.

1. One of them is state function reduction for M-matrix reducing as a special case to what is known as state preparation (reduction) for the positive (negative) energy part of the state. Since quantum numbers of the positive energy part of the zero energy state couple directly to the space-time geometry [K119], quantum numbers are mapped to classical variables (zero modes) in state function reduction in accordance with the basic hypothesis of the standard quantum measurement theory.

2. The selection of quantization axes is a further choice and means a localization to a particular sector of WCW for which the geometry of causal diamonds codes for the preferred measurement axis. A selection of single CD from quantum superposition of CDs would mean localization of the lower and upper times of CD. This does not seem to be consistent with the assumption that energy momentum eigenstates are in question and only approximate localization is expected to be possible. A further selection is selection of the page of the Big Book defined by the generalized embedding space meaning also a selection of the value of Planck constant.

3. An example about a more abstract choice could be the selection between entropic and negentropic entanglement. If this choice, which essentially means selection of rationals from the continuum of reals or p-adics, is possible it could serve as the physical correlate for the choice between good and evil. One might argue that this selection is made possible at space-time level by the intersection of real and p-adic variants of the embedding space. At WCW level it could correspond to a more abstract intersection with the counterpart of rationals identified as light-like 3-surfaces represented by rational functions with rational coefficients identifiable as common to real and p-adic worlds. State function reduction to the intersection of p-adic and real worlds would induce also the rationality of entanglement probabilities since they must make sense both p-adically and in real sense. One might say that the enlightenment means living in both real and p-adic world simultaneously.

4. These two interpretations for the intersection of real and p-adic worlds need not be independent. The absence of definite integral in p-adic number fields suggests that the transition amplitudes between p-adic and real sectors must be expressible using only the data associated with rational and common algebraic points (in the algebraic extension of p-adic numbers used) of embedding space. This intersection is discrete and could even consist of a finite number of points. For instance, Fermat's last theorem tells that the surface $x^n+y^n=z^n$ contains

only origin as rational point for $n = 3, 4, ...$ whereas for $n = 2$ it contains all rational multiples of integer valued points defining Pythagorean triangles: this is due to the homogenuity of the polynomial in question. Therefore p-adic-to real transition amplitudes would have a purely number theoretical interpretation. One could speak of number theoretical field theory as an analogy for topological field theory.

Why selves would then tend to chose the evil? Perhaps the reason is that this choice almost decouples the system from the external world and provides maximum freedom for action whereas strong negentropic entanglement reduces the number of degrees of freedom. The freedom is nice as long as the system is able to keep the entanglement entropy below the critical value and therefore avoids death as the prize of the sin. Note that even if the system identified at a given level of hierarchy behaves a saint, it probably happens that some of its subsystems are sinners. This conforms with the interpretation that meditative states involve minimum number of mental images so that there are not many sub-systems performing the wrong choices. One can of course claim that the sinners are needed since they lead to the re-organization and evolution of the system by destroying existing structures based on negentropic entanglement. Eternal life would be a catastrophe since it would not allow any evolution at all.

One could say that a healthy system consists of maximally alert subsystems able to stay wake-up by generating negentropic entanglement. This raises the question what "getting tired" means.

1. Getting tired could mean death of mental images: the entanglement of sub-selves with the external world becomes entropic and nearly critical leading eventually to the death of mental images and the system becomes drowsy. If also the system itself generates entropic entanglement it falls into sleep identified as a loss of consciousness. The interaction with the external generates mental images and these sub-selves in turn tend to generate also entropic entanglement since only few of them are saints. This would mean that the dying of mental images is equivalent with getting tired.

2. In principle it would be possible to remain conscious by generating negentropic entanglement instead of sleep and perhaps meditative practices allow to achieve this. The question is why ordinary people are not able to achieve this by just getting tired. The first thing to notice is that meditators tend to get rid of their mental images. The sensory input and also thoughts are systematically eliminated. If entanglement entropy for the system is sum of the entanglement entropies of the various levels in the hierarchy assignable to the system (hierarchy of CDs and space-time sheets) then englightment is facilitated by enlightenment at lower levels and getting tired by entropic entanglement of mental images tends to lead to a loss of consciousness at the higher levels. Meditative practices indeed emphasize whole body consciousness achieved by exercises involving directed attention to all body parts. If all levels of the self hierarchy below given level contribute to the entanglement entropy then all length scales below the given length scale are relevant for the ability of the system generate negative entanglement entropy. Unless highly negentropic entanglement is possible in longer length scales (say at dark space-time sheets) the evolution of consciousness must proc

3. The proposed interpretation means that sleep identified as a loss of consciousness is in a well-defined sense regression. One can of course ask whether sleep really means a loss of consciousness: could it be that only memories are lacking from this period? Even if a loss of consciousness is in question as the arguments above suggest sleep could have many vital functions. For instance, the resting state would mean absence of sensory input at various levels and the absences of mental images would make easier for the subsystems to generate negentropic entanglement by meditating. Note that one can even consider the possibility that consciousness always means negentropic entanglement.

From the energetic point of view metabolism means the transfer of the metabolic energy from the nutrients to the system. This energy is ordered energy so that the energy feed can be seen as a feed of negentropy. One could perhaps say that biosystem "eats" negentropic entanglement or the ability to generate it.

1. The chopping of the nutrient molecules to their basic building bricks and the reconstruction of proteins and other bio-molecules from them would detach from the nutrient molecules the negentropic entanglement and leave only the waste having entropic entanglement with the external world. This raises some questions. How the interaction of the biomolecules of the body with the molecules of the nutrient leads to the transfer of the negentropic entanglement? Is the negentropic entanglement assignable to particular parts of the nutrient molecule transferred to the receiving system? How the fundamental ADP$\rightarrow$ATP Karma's cycle relates to the transfer of entropic entanglement? Is phosporus ion perhaps a standardized negentropic entangler?

2. If magnetic flux tubes carrying dark matter serve as correlates for entanglement and also directed attention as assumed in the model of DNA as topological quantum computer [K5] then the transfer of negentropic entanglement would correspond to a re-connection of the magnetic flux tubes having direct information theoretic interpretation since the flux tubes serve as a correlate for the program of topological quantum computer. The end of a dark magnetic flux tube would be transferred from the nutrient molecule to a molecule of the living system providing it with negentropic entanglement. This would also provide a deeper level explanation for why the nutrients must be organic molecules.

From above one can conclude that illness as a failure to self-organize in normal manner is basically a failure to generate normal patterns of self-hierarchy. Some part of biosystem does not receive the needed entanglement negentropy feed. "Metabolism does not work properly" would be a more familiar manner to state the same thing. The mysterious ability (from classical physics point of view) of a self-organizing system to repair itself (get cured) can be understood as a consequence of the fact that system ends up with some self-organization pattern (fixed point of iteration) automatically. The new element would the presence of choices between good and evil at every level of the hierarchy.

Some examples are useful in the attempt to concretize these ideas.

1. Healthy heart is sufficiently chaotic, not ordered. Quite generally, living systems seem to reside at the border between chaos and order. Suppose that "chaotic" really means chaotic rather than just complex. The border between chaos and order could be seen as a compromise in which the external energy feed creates a large enough number of patterns allowing to form representations about external world but does not yet lead to a total loss of negentropic entanglement at various levels of hierarchy. This borderline would naturally correspond to quantum criticality which can have several interpretations. One of them is as criticality with respect to the phase transitions changing the value of Planck constant.

2. According to TGD based model of nerve pulse and EEG [K82, K37], EEG is directly related to the oscillations of various Bose-Einstein condensates associated with neurons and possibly also glial cells. Large group of neurons could have simultaneously negentropic entanglement during coherent oscillations and synchronous firing could serve as a correlate for this collective behavior. Nerve pulse patterns could reflect a temporal loss of this coherence as individual neurons generate entropic entanglement and start to behave as individuals. The interpretation of spike patterns as communications indeed requires that neurons behave as separate selves. If the coherence of EEG is lost, neuron group ceases to behave like a coherent unit firing synchronically. The spatial coherence of EEG in brain could serve as a measure for the quantum coherence of brain. The spatial coherence EEG is indeed known to reflect psychic disorders. Similar loss of coherence could explain the behavior of cancer cell population and an interesting possibility is that some EEG type collective oscillation is missing from cancer cell population. If magnetic flux tubes serve as correlates of negentropic entanglement, de-coherence could reduce to a disorder of the magnetic body.

3. Both rising and lowering of the body temperature leads to the lowering and even loss of consciousness. The development of organisms able to control their body temperature and thus stay conscious in wide range of external temperatures is regarded as one the great evolutionary steps. A natural interpretation for the narrow range of physiological temperatures is in terms of quantum criticality vital for the possibility to self-organize to a large number of widely

differing patterns making possible to react to the changing environment and form sensory and cognitive representations about it. For instance, the lipid layers of cell membranes are in liquid crystal phase only in narrow range of temperatures. Too low temperature means that the lipids are frozen. If the magnetic flux tubes connecting nucleotides of DNA to lipid layers define the braids involved with quantum computation, freezing makes quantum computations impossible [K5]. Too high temperatures in turn make the motion of lipids too chaotic. Also the quantum entanglement between the ends of flux tube can become entropic. Hallucinations associated with the fever could perhaps be regarded as a pathological state in which the feedback from brain generating virtual sensory input to sensory organs begins to dominate.

10.3 Haken's Theory Of Self Organization

Haken's classical theory of self-organization and the related model of pattern recognition (see the book "Information and Self-Organization" [B23]) is rather attractive in its simplicity and generality. Of course, the model cannot tell how the conscious experience associated with the pattern recognition is created but the concept of quantum jump might provide this lacking piece. The model generalizes also to a description of how biosystem acts on external world.

The potential wells representing attractors of the classical dynamics of the order parameter are replaced by the maxima of the Kähler function with respect to non-zero modes in quantum TGD based model. The zero modes of WCW geometry serve as control parameters and maximum depends on them. There are several maxima for given values of zero modes so that a typical catastrophe theoretic situation results and non-equilibrium phase transitions become possible.

10.3.1 Haken's Theory Of Non-Equilibrium Phase Transitions

The basic elements of Haken's theory [B23] are the concepts of order parameter and Slaving Hierarchy, Langevin and Focker Planck equations, maximum entropy principle and non-equilibrium phase transitions associated with the fluctuations of the order parameter at criticality.

Dynamical variables

Order parameters, denote them by q, are the fundamental dynamical variables in Haken's theory. They could be chemical concentrations, densities, some parameter specifying the geometrical conformation of system, etc. The basic element in Haken's theory is master-slave hierarchy. Slave possesses swift dynamics which follows the much slower dynamics of the master. Master typically appears as an external slowly varying parameter in the dynamics of the slave. In TGD larger space-time sheet, external world, typically serves as a master of the smaller space-time sheet, perceiver, in sensory perception. Situation could be also reversed: the reaction to the sensory experience is good example of this! p-Adic length scale hierarchy is a good example of master-slave hierarchy.

Dynamics

The dynamics of the order parameter is determined by a dissipative force proportional to the time derivative dq/dt of the order parameter, conservative force field defined as a gradient of a potential function $V(q)$ and random fluctuating force $F(t)$. In equilibrium the velocity is determined from the requirement that acceleration vanishes and this condition is known as Langevin equation. Potential function contains as external parameters the slowly varying order parameter of the master.

Fokker-Planck equation describes the devopment for the probability distribution $f(q,t)$ associated with the order parameter (an ensemble of identical systems is assumed: for instance, cells could form this kind of ensemble). Fokker-Planck equation is just the continuity equation for the probability density and the associated probability current containing convective term $\nabla_q V f$ proportional to the gradient of the potential $V(q)$ and a diffusive term proportional to the gradient $\nabla_q f(q,t)$ of the probability density.

Equilibria and maximum entropy principle

In non-equilibrium thermodynamics the requirement that entropy is maximal implies that in equilibrium situation the probability density $f(q)$ is proportional to the exponential of the potential function $V(q)$ and is hence analogous to Boltzmann weight:

$$f_{eq}(q) = Nexp(-\frac{V(q)}{K}) \ .$$

K is analogous to temperature. V determines single particle correlation functions $\langle q_i \rangle$, two-particle correlation functions $\langle q_i q_j \rangle$ and also higher correlation functions for the components of the order parameter and this gives means of deducing the function V from experimental data. Typically a Gaussian modified with a fourth-order interaction terms is in question. There is a direct analogy with Higgs potential and non-equilibrium phase transitions have interpretation as symmetry breaking/restoration.

Non-equilibrium phase transitions

Non-equilibrium phase transitions are induced by a change in some parameter of the potential, typically the coefficient b of the quadratic term in

$$V = bq^2 - aq^4 \ ,$$

which represents master type order parameter itself. For instance, single potential well ($b < 0$) becomes unstable when b becomes positive ($b > 0$) and order parameter moves to either well of the double well potential. In a deformed potential Langevin equation leads rapidly to a new attractor corresponding to the free energy minimum of the potential: order parameter is captured by the nearest attractor. In Focker Planck equation spontaneous symmetry breaking with a selection of second potential well occurs.

10.3.2 Pattern Recognition In Haken's Theory

1. Perception gives rise to order parameter describing information about the external world. Visual field of the eye is a good example.

2. Each attractor of the order parameter dynamics corresponds to a characteristic pattern, feature. Grandma, apple, etc..

3. Pattern recognition is essentially feature detection and completion of the pattern to one of the characteristic patterns. Features are preferred patterns of q, which correspond to the minima of the free energy associated with the order parameter in question. Formally, features correspond to the eigenvectors of the quadratic part of the free energy determined by the inverse of the quadratic form defined by the correlation functions of the components of the order parameter.

4. Perception creates a pattern of the order parameter q. If the system is above criticality (there is minimum feed of metabolic energy to guarantee that one has $b > 0$ in the potential function) this leads to a rapid dynamics (Langevin equation) leading from the pattern near an attractor to the attractor, the feature. The dynamics clearly creates caricatures.

10.4 Non-Equilibrium Thermodynamics And Quantum TGD

Quantum TGD suggests the replacement of Haken's theory with a quantum description based on the generalization of the Thom's catastrophe theory to WCW context ("world of classical worlds", briefly WCW) and the introduction of spin glass analogy and p-adic fractality at the fundamental level.

1. If the space of 3-surfaces with fixed values of zero modes is infinite-dimensional symmetric space [K30], one can expect that there is a single maximum of Kähler function in quantum fluctuating degrees of freedom and that one can effectively consider only the maximum just as in the case of integrable quantum systems.

2. Zero modes correspond to non-quantum fluctuating degrees of freedom and define a natural quantum counterpart of control variables. As already explained, under rather general assumptions it is possible to have have a hierarchy of wave functions with 2n-dimensional locus in zero modes and reducing effectively to the exponent of Kähler function. Therefore the maxima of Kähler function with respect to zero modes define an effective discretization of zero modes and give rise to the counterpart of spin glass energy landscape.

3. The discretization of the partonic 2-surfaces X^2 by replacing them with the discrete set of the loci of fermions at X^2 is the counterpart for the finite measurement resolution. This means the replacement of light-like 3-surfaces with braids and a connection with topological quantum field theories. At space-time level one has 2-dimensional string world sheets connecting the braid strands belonging to separate light-like 3-surfaces and a connection with string model based description emerges. If stringy effects can be neglected, discretization effectively replaces WCW with a finite cartesian power of embedding space. Note that the induced Kähler form of CP_2 associated with space-time sheet defines important class of zero modes and this information is lost in this approximation. In any case, in these approximations TGD based theory would be finite-dimensional and would in many respects resemble Haken's theory.

There are also several profound differences.

1. p-Adic length scale hypothesis is an essential part of TGD based approach and makes possible quantitative predictions based on simple scaling arguments. A more speculative hypothesis is that infinite primes characterize the p-adic length scale assignable to a light-like 3-surface so that a given sector of WCW would be characterized by infinite prime. The latter assumption does not have practical implications.

2. The hierarchy of Planck constant implying the generalization of the notion of embedding space plays a key role in biological applications. Magnetic flux tubes would serve as correlates for entanglement and directed attention. The contraction and lengthening of magnetic tubes induced by the phase transitions changing Planck constant and their reconnection could define the basic mechanisms of bio-catalysis. Magnetic flux tubes would also serve as braids and make possible topological quantum computations.

3. Quantum criticality means that space-time surfaces are critical in the sense that there is an infinite number of deformations of the space-time surface with a vanishing second variation of Kähler action [K119]. In the framework of catastrophe theory this means that the system resides at the critical manifold for which several (now infinite number of) branches defined by the extrema of potential function co-incide so that the rank of the matrix defined by the second derivatives of the potential function is reduced and even some higher derivatives can vanish (as in the tip of the cusp catastrophe). These critical manifolds define an inclusion hierarchy just as in Thom's theory and to this hierarchy one can speculatively assign inclusion hierarchy of super-conformal algebras and of hyper-finite factors of type II_1, which play a key role in the formulation of quantum TGD.

   The natural expectation is that the number of critical deformations is infinite and corresponds to conformal symmetries naturally assignable to criticality. The number n of conformal equivalence classes of the deformations can be finite and n would naturally relate to the hierarchy of Planck constants $h_{eff} = n \times h$ (see **Fig. ??** in the appendix of this book).

4. One cannot avoid bringing in also quantum theory of consciousness. Zero energy ontology replaces classical state with zero energy state analogous to a physical event or process, and S-matrix is replaced with the pair defined by U-matrix and M-matrix. U-matrix characterizes quantum jumps between zero energy states and makes possible volitional action. M-matrix characterizes zero energy states and is assigned with perception. Quantum jump corresponds

to perception-reaction pair and defines the counterpart for the basic iterative step of self organization (note that state function reduction and state preparation combine to a single state function reduction in zero energy ontology). NMP defines the variational principle of consciousness theory. The notion of number theoretical Shannon entropy brings in the choice between quantum jumps generating positive *resp.* negative entanglement entropy. This choice between co-operation and maximal independence could be a correlate for a conscious choice between good and evil. This aspect should allow a statistical description in terms of a probability of being sinner or saint.

10.4.1 Spin Glass Analogy

At the level of WCW geometry spin glass analogy is well understood. The WCW CH consisting of 3-surfaces in H has fiber space structure. Fiber corresponds to nonzero modes of WCW metric contributing to the line element of metric and base corresponds to zero modes in which line element vanishes (see **Figs. 10.1**, **10.2**). Spin-glass analogy implies large degeneracy of the absolute minima of Kähler action. In the approximation that classical gravitation can be neglected all extremals of Kähler action are degenerate and CP_2 canonical transformations are $U(1)$ gauge symmetries in fiber degrees of freedom: actually however $U(1)$ gauge symmetry is broken and the gauge-related space-time surfaces are not gauge-equivalent configurations so that spin-glass analogy results. The functional integration around maxima of Kähler function as function of fiber coordinates gives well define results since Gaussian determinant and metric determinant cancel each other.

The localization in zero modes around single maximum of Kähler function in quantum jump could mean that they are equivalent with measurement resolution. Symmetric space property in turn suggest that the integration over fiber degrees of freedom reduces to an integral around single maximum of Kähler function. This would mean huge simplification in the construction of the theory since very close resemblance with the formalism of quantum field theory would results as a consequence. The physical picture of quantum field theories certainly suggests this strongly.

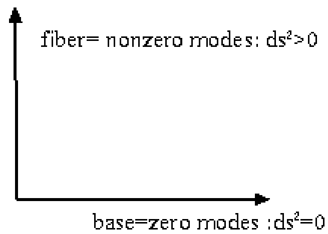

Figure 10.1: WCW has fiber space structure. Fiber corresponds to coordinates appearing in the line element and base to zero modes, which do not appear in the line element.

10.4.2 Maxima Of The Kähler Function As Reduced Configuration Space Ch_{red}

When one calculates the probability amplitude for a given quantum jump, given as the inner product between WCW spinor fields, one obtains an integral of the fermionic Fock space inner product as a functional of 3-surface X^3 over fiber degrees of freedom around maxima of Kähler

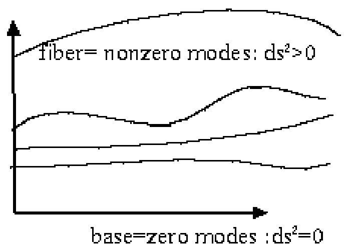

Figure 10.2: The reduced WCW CH_{red} has many-sheeted structure with each sheet parameterized by zero modes.

function as function of fiber coordinates: if the most optimistic expectations are realized, only single maximum contributes. This integral can be calculated approximately by performing Gaussian perturbation theory. Thus the *maxima* of the Kähler function, which are completely analogous to the free energy minima of spin glass, can be identified as the reduced WCW CH_{red}. The ill defined Gaussian and metric determinants cancel each other and the non-locality of Kähler function as a functional of 3-surfaces implies that the standard divergences of the local quantum field theory are absent.

The number of maxima for given values of zero modes can be large: This is in fact expected since only classical gravitational action differentiates between symplectic transforms of a given preferred extremal. In particular, the presence of mind-like space-time sheets is expected to give rise to huge degeneracy. Thus CH_{red} has many-sheeted structure which each sheet parameterized by zero modes and a generalization of catastrophe theory to infinite-dimensional context is needed to describe the situation mathematically. This degeneracy corresponds in the simplest case to the degeneracy of state associated with cusp catastrophe (see **Fig. ??**) and phase transition like quantum jumps corresponds to selection of one of the various allowed branches.

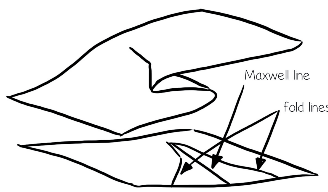

Figure 10.3: Cusp catastrophe. In this case CH_{red} has two sheets (intermediate sheet is not maximum of Kähler function).

The simplest manner to understand the expected decomposition of the reduced WCW to different regions D_P characterized by a collection of p-adic primes is to assume that $exp[K_{max}]$ is p-adic fractal as a function of the zero modes. p-Adic fractality is suggested both by criticality and by spin glass analogy. p-Adic fractality implies automatically ultra-metric hierarchy at the level of WCW allowing the decomposition of CH_{red} to a tree like structure. This kind of hierarchy is suggested by Parisi [B21] to be fundamental for the biological information processing, especially for the formation of concepts and classification into categories.

10.4.3 The Concepts Of Quantum Average Effective Space-TimeAnd Many-Sheeted Space-Time

If the most optimistic expectations hold true, functional integration in fiber degrees of freedom reduces to integration around some maximum X^3_{max} of Kähler function with respect to fiber coordinates. It is convenient to identify the space-time surface $X^4(X^3_{max})$ as "quantum average effective space-time". Since WCW integration occurs over the sector D_p associated with the final state of the quantum jump, effective quantum average space-time characterizes final state and can be regarded as a representative example from the set of space-time surfaces appearing in the final state, which all have same macroscopic characteristics.

One can associate this space-time surface only with the final state of the quantum jump and the sequence of quantum jumps defines a sequence of space-time surfaces of this type. As already explained, dissipative time evolution could be interpreted as kind of envelope for this sequence of reversible time evolutions. TGD however allows to code for thermal parameters to space-time geometry via the coupling of the Kähler-Dirac action to average values of the quantum numbers for the positive energy part of the state. Classical Langevin dynamics for order parameters can be identified as the counterpart of the hopping in zero modes and in degrees of freedom characterizing various degenerate absolute minima associated with the maxima X^3_{max} of Kähler function.

A new element related to quantum average space-time relates to how GRT emerges as a limit of TGD. GRT space-time as effective space-time is obtained by replacing many-sheeted space-time with Minkowski space with effective metric determined as a sum of Minkowski metric and sum over the deviations of the induced metrices of space-time sheets from Minkowski metric. Poincare invariance suggests strongly classical Equivalence Principle for the GRT limit in long length scales at least. One can consider also other kinds of limits such as the analog of GRT limit for Euclidian space-time regions assignable to elementary particles. In this case deformations of CP_2 metric define a natural starting point and CP_2 indeed defines a gravitational instanton with very large cosmological constant in Einstein-Maxwell theory. Also gauge potentials of standard model correspond classically to superpositions of induced gauge potentials over space-time sheets.

Gravitational constant, cosmological constant, and various gauge couplings emerge as predictions. Planck length should be related to CP_2 size by a dimensionless numerical factor predicted by the theory. These constants need not be universal constants: cosmological constant is certainly very large for the Euclidian variant of GRT space-time. These constants could also depend on p-adic length scale. p-Adic coupling constant evolution suggests itself as a discretized variant of coupling constant evolution and p-adic scales would relate naturally to the size scales of causal diamonds: perhaps the integer n characterizing the multiple of CP_2 scale giving the distance between the tips of CD has p-adic prime p or its power as a divisor.

At microscopic level one has many-sheetedness. Sheets themselves are extremely simple objects as preferred extremals of Kähler action analogous to Bohr orbits and provide the analogs of atoms for GRT space-time which is much more complex. Zero Energy Ontology means that the 3-surfaces defining the ends of space-time surface at the light-like boundaries of causal diamond would fix the space-time surface highly uniquely. The preferred extremal property gives a non-trivial correlation between the ends analogous to that for the ends of Bohr orbit.

Zero energy ontology implies also that the maxima of Kähler function correspond to preferred time evolutions since the maximum property fixes both ends of the space-time surface. Entire temporal self-organization pattern become basic objects. In the applications to biosystems this is of utmost importances and gives hopes of understanding processes like morphogenesis which look mysterious in positive energy ontology.

The notion of magnetic body is central in TGD inspired quantum biology [K78]. Magnetic body contains dark matter identified as a phases of ordinary matter with large effective value of Planck constant $h_{eff} = n \times h$. Magnetic body controls biological body, receives sensory input from it, and parts of it serve also as templates for its formation. Phase transitions changing the value of h_{eff} and thus flux tube lengths provide basic mechanisms of bio-catalysis. Cyclotron radiation with large value of h_{eff} can have energy above thermal energy and allows the control of biochemical reactions if the dark photon energies are in the visible and UV range assignable to biophotons.

What is important that magnetic body is 4-dimensional so that its time evolution can code for morphogenesis. Replication would basically reduce to that for 3-D magnetic body and would correspond to a fundamental vertex analogous to 3-particle vertex for Feynman diagrams. Already in 3-D context the braiding of the magnetic body brings in possibility of topological quantum computation using braiding of the flux tubes. In 4-D context braiding is replaced by 2-braiding occurring for string world sheets defined by the flux tubes idealized to string. String world sheets emerge also as real objects the modes of Kähler-Dirac equation are localized at 2-D surface from the condition that electromagnetic charge is well defined. 2-braiding brings in besides ordinary braiding also reconnection of flux tubes and one ends up to a speculation that DNA sequences actually code for the 2-braiding of the magnetic body.

10.4.4 Haken, Thom, Penrose And Hameroff

The picture leads to a generalization of Haken's theory of non-equilibrium phase transitions to a Penrose-Hameroff type picture [J45]. Any quantum jump corresponds to a selection of space-time surfaces as the relevant maximum of Kähler function and the fundamental order parameters are the zero modes characterzing the space of these 3-surfaces. Non-equilibrium phase transitions correspond to quantum jumps leading to a selection of one maximum, from a quantum superposition of several ones appearing in the state $U\Psi_i$. The classical theories of Haken and Thom correspond to the hopping motion in zero modes. The sequence of quantum jumps leads to the regions of WCW at which vacuum functional is maximum and when Kähler function has several maxima this leads with great probability to hopping from one sheet of the catastrophe surface to another. For volitional quantum jumps selecting between maxima of Kähler function in fiber degrees of freedom, one ends up with the quantum versions of these theories in which genuine phase-transition like quantum jump selecting between the sheets of the catastrophe surfaces occurs near the "Maxwell line": the Penrose-Hameroff proposal [J45] for the orchestrated reduction of state function is analogous to this kind of selections.

10.4.5 Classical Gravitation And Quantum Self-Organization

The symplectic transformations of CP_2 acting as local $U(1)$ gauge transformations leave zero modes invariant since they do not affect the induced Kähler form of CP_2. The classical gravitational interaction breaks local $U(1)$ invariance as a gauge symmetry of the Kähler action and means that the action of a symplectic transformation spoils the preferred extremum property in general: gauge degeneracy transforms to spin glass degeneracy in 4-D sense. This means that symplectic transformation become dynamical symmetries acting as symplectic transformations only at the partonic 2-surfaces defined by the intersections of wormhole throats with the boundaries of causal diamonds. In the interior of space-time sheet their action is not symplectic anymore and Kähler action is affected: this is necessary for having a non-trivial Kähler metric in WCW . The symmetric space property for the preferred extremals suggests that there is single maximum of Kähler function at the orbit of the symplectic group defined by the symplectic deformations of the partonic 2-surface.

The value of the Kähler action depends only very weakly on the symplectic degrees of freedom. Hence one expects a large number of space-time sheets with almost identical value of Kähler function. Only the contribution of the induced metric proportional to R^2 (R denotes CP_2 radius) distinguishes between almost degenerate extremals in the lowest approximation. Since space-time surfaces code for the four-momenta of partons [K119], one expects that the contribution is expressible in terms of quantities GM_i/L, where M_i are mass parameters and L a length scale naturally defined by the size of CD. This kind of expression indeed follows from general arguments for the form of the measurement interaction term. For $L >> 2GM$, (Schwartschild radius) one has $GM/L << 1$. This situation corresponds to a non-perturbative situation in the sense that a very large number of preferred extremals gives a sizeable contribution to the vacuum functional.

Non-perturbative phase seems to emerge also in different manner above Planck mass scale. The coupling constant parameter $GM_1M_2/\hbar$ is analogous to gauge coupling strength $\alpha = g^2/4\pi\hbar$ appearing in perturbation theory. It becomes large above Planck length scale and one can argue that perturbation theory fails. On basis of the experience with hydrogen atom one can also argue that also the non-perturbative quantum description of gravitationally bound states in terms of Schrödinger equation fails. The proposal is that the hierarchy of Planck constants saves the situation [K92, K71]: a phase transition increasing $\hbar$ and guaranteeing the smallness of $GM_1M_2/\hbar$ takes place. Equivalence Principle fixes the form of $\hbar_{gr}$ to $\hbar_{gr} = GM_1M_2/v_0$, where $v_0 < 1$ corresponds physically to a velocity. Planck length redefined as $\sqrt{G\hbar_{gr}}$ is transformed to $GM/\sqrt{v_0}$ and is of the order of Schwartshild radius. Above this length scale non-perturbative phase prevails if the previous argument is accepted. The implication would be macroscopic quantum coherence at astrophysical scales with a gigantic value of Planck constant at the space-time sheets mediating gravitational interaction [K92, K71].

For condensed matter densities Planck mass corresponds to the length scale of 100 μm defining the size scale of a large neuron. These observations suggest that macroscopic quantum phases at the space-time sheets mediating gravitational interaction are fundamental in TGD and also in TGD inspired quantum biology. The almost degenerate preferred extremals could define the TGD counterpart for the gravitationally degenerate microtubule conformations of Penrose and Hameroff [J45]. In Penrose-Hameroff theory gravitons are believed to play important role. The vacuum Einstein tensor associated with the preferred extremals (say massless extremals) is indeed expected to generate a coherent state of gravitons characterized by large value of Planck constant so that $E = hf$ relationship implies that very low frequency gravitons are energetic. An interesting possibility is that these coherent states of gravitons give rise to the sense of proprioception.

10.4.6 Quantum Model For Perception And Reaction

All quantum jumps involve both active and passive aspects of consciousness and it is interesting to look for a general model for active and passive aspects of consciousness based on the generalization of Haken's theory. Before continuing, one must notice that the meaning of the active-passive dichotomy depends on one's tastes. One could argue that the genuinely active aspect corresponds to the U process generating the quantum superposition of possibilities and that the subsequent selections correspond to the passive aspect. Also volition as a selection between given options would be a passive aspect. Second interpretation is that only that part of the selection process which has a clear identification in terms of volitional acts corresponds to the active aspect whereas perception would correspond to the passive aspect. It is however known that sensory perception is to some extent a process involving also a selection between alternative sensory percepts (binocular rivalry).

Consider first the general picture.

1. In TGD the fundamental order parameters correspond to the zero modes of WCW . Kähler-Dirac action containing a measurement interaction term couples various conserved quantum numbers to the dynamics of the space-time surface so that standard quantum measurement theory results. Since partonic 2-surfaces carry the quantum numbers the coupling is to the zero modes characterizing the induced Kähler in the interior of the space-time surface.

2. In positive energy ontology volitional acts would select between initial values defining initial value sensitive dynamical developments of the 3-surface. In zero energy ontology the selection is between entire time developments, which are not deterministic in the standard sense of the world. This means a hierarchy selections at various time scales associated with the hierarchy of CDs. Quantum criticality is a more natural notion than initial value sensitivity in this framework. The fractal hierarchy of criticalities means that critical manifolds contain catastrophe surfaces which in turn have critical surfaces.

3. The outcome of the selection process is 4-D dynamical pattern rather than time=constant snapshot. This interpretation is especially natural in living matter where spatio-temporal EEG patterns characterize the state of brain.

4. Besides state function reduction in geometric degrees of freedom there are selections in spin degrees of freedom of WCW spinor field. Zero energy WCW spinor fields allow interpretation as superpositions of Boolean statements and the natural interpretation would be that state function reduction in these degrees of freedom gives rise to Boolean cognition and WCW spinor fields represents rules of type $A \to B$ as superposition of all instances. Boolean cognition would be analogous to sensory perception.

In TGD framework the dynamics for order parameters corresponds basically to hopping in the space of order parameters. Therefore the statistical description of hopping as a continuous motion is expected to be an excellent approximation. The motion is much like Brownian motion in presence of drift term. Langevin dynamics for order parameters can be regarded as a model for the hopping in the space of order parameters. Focker-Planck dynamics applies, when the number of nearly identical space-time sheets each characterized by zero modes is large so that one can apply quantum statistical determinism. One can also introduce probability distribution also for single space time sheet to describe the distribution of zero modes defined by quantum jumps during some macroscopic time scale.

The hopping in the space of order parameters must lead to the region of order parameter space in which the modulus squared of the configuration space spinor field has maximum. The simplest situation is that the maxima correspond to the maxima of vacuum functional as function of order parameters. Since vacuum functional is exponential of Kähler function, this means that Kähler action for space-time sheet representing subsystem containing zero modes as external parameters takes the role of the potential function in Haken's theory.

If sensory experience is determined by the localization in zero modes then feature detection must correspond to Langevin type dynamics leading to some minimum of potential function and in TGD it corresponds to a hopping motion leading to attractors defined by several maxima of the Kähler function as a function of zero modes. For instance, in the case of cusp catastrophe quantum jumps lead rapidly from the stable sheet of catastrophe to another in the vicinity of Maxwell line. Conscious feature detection would require that there is sub-self defining mental image whose sensory experience is dictated by the localization in zero modes characterizing feature. It seems that this requires macroscopic quantum phases whose order parameters in ground state are determined by the values of zero modes. The essentially quantal element of the feature detection is the wake-up of the sub-self whose subsequent self-organization gives rise to a mental image depending only weakly on initial conditions. A general model for this wake-up mechanism is based on the quantum jumps induced by Josephson currents running between two superconductors representing master and slave. These quantum jumps are induced resonantly in slaved superconductor, when the frequency of the Josephson current corresponds to the energy difference for the states of the slaved superconductor [K73, K72].

The recognition of phonemes takes place in definite places in the linguistic regions of brain. This suggests that the same input comes into each of these detectors and gives rise to yes-no response so that cusp catastrophe would be in question. The assumption that various phoneme detectors receive same input data is in accordance with the ideas about hologram like data representation in brain. Generalizing, it seems that some parts brain could be to some extent act as a collection of simple yes-no feature detectors receiving essentially the same input.

10.4.7 Are Proteins Quantum Spin Glass Type Systems?

The entire universe should be quantum spin glass type system if TGD is correct. There is indeed some evidence for the spin glass nature of biosystems at protein level [I75, I75]. A long standing problem of molecular biology is to understand why proteins [I104] fold to very few preferred spatial conformations only [I95, I21]. I have discussed a TGD inspired model for protein folding [K8], which is completely unrelated to the following discussion.

A naïve expectation, assuming *random* amino-acid sequences, is that folding should occur randomly. It would however would however require the age of the Universe for the protein to fold in this manner [I21]. According to the article [I75, I75], Ken Dill has simulated proteins using a simplified computer model in which the 20 amino-acids are replaced with 2 model amino-acids: "hydrophobic" or "hydrophilic". It has turned out that only few per cent of these virtual proteins are good folders. The lesson seems to be that random sequences of amino-acids are not sufficiently protein like and that good folders have some specific property allowing them to arrive at a unique shape.

Could protein spin glass energy landscape have single deep valley

According to the same article, Peter Wolynes suggests that proteins are spin glass type systems characterized by a fractal like energy landscape containing very many nearly degenerate energy minima. This means that system has difficult time in finding low energy arrangements and it can end up to any one of the very many energy minima with almost degenerate energies. Therefore *typical* spin glass like system is not a good folder. Wolynes suggest that, as a consequence of natural selection, real proteins differ from random proteins in that they have one deep energy minimum besides shallow minima still present. The energy landscape is still rugged but now there is one preferred configuration at the bottom of a deep energy valley. Also the states near this state are assumed to have energy below the average energy. This funnel like structure in energy landscape is proposed to be a solution to the folding paradox. One can understand the correct folding to result from external perturbations: if protein is put in hot liquid, thermal perturbations take care that it is not left in any local energy valley during cooling but ends up to the deep energy minimum. Minimization of free energy could also selet good folders during evolution starting from a soup of random amino-acid sequences.

If protein is in self state, quantum jumps inside it occur and imply quantum self-organization leading toa preferred final state pattern selected by dissipation. This pattern represents protein folding depending on the external parameters like pH, ionic concentrations and temperatures whereas the dependence on the initial state is very weak. Thus the phenomenon of protein folding gives direct support for the self-hierarchy and consciousness in even protein length scales.

One can also try to estimate the time scales involved. According to [I104] the time times for protein folding vary in the range $10^{-1} - 10^{3}$ seconds both in vivo and vitro. According to Wikipedia article [I21] the times for small proteins with lengths up to hundred residues fold in single step and the time scale is 1 millisecond and the shortest time scales are in microsecond range. The question is whether these time scales could be understood without making any dynamical assumptions by using only p-adic length scale hypothesis.

1. The naïve application of p-adic length scale hypothesis before zero energy ontology would suggest that the duration of the protein self is of order $T_p = L_p/c = L(k)/c$ for $p \simeq 2^k$. For the p-adic length scale $L(151) \simeq 10^{-8}$ meters (cell membrane thickness) this gives $T_p \sim 10^{-15}$ seconds. This time scale is quite too short.

2. One might argue that in zero energy ontology the secondary p-adic time scale $T_{2,p} = \sqrt{p}L_p$ of the CD, where the p-adic length scale L_p characterizes the protein or the folding mechanism is relevant. One can consider several identifications of L_p. What comes first in mind are the length of the protein, the size scale of the folded protein, and the thickness of the amino-acid sequence. Also the p-adic length scale of electron or proton inducing catalytically crucial steps in the folding of short proteins could determine $T_{2,p}$. For $k = 151$ (cell membrane thickness) this would give a time scale of order 10^5 seconds, roughly 50 hours. $k = 145$, which corresponds to nanometer length scale and thickness of the protein, would give a time scale of one hour, which corresponds to the experimental upper bound according to [I104].

   $k = 127$ corresponding to electron would give a secondary time scale of .1 seconds, which is the lower bound according to [I104]. The interpretation could be that single electron initiates the folding process catalytically. Millisecond would correspond to $L(k = 120) \sim 10^{-13}$ m. This could correspond to the p-adic scale for quarks with mass about 5 MeV. Quarks and antiquarks indeed appear at the ends of (wormhole) magnetic flux tubes in the model of DNA as topological quantum computer. If the interpretation is correct the two fundamental time scales of living matter would correspond to elementary particles. The fastest time sale of order microsecond could correspond to the p-adic length scale of proton giving a time scale of order 10^{-7} s: this could make sense if proton is essential for the catalytic step involved. I have indeed proposed that the dropping of electrons and protons between space-time sheets defines key element of bio-catalysis [K8].

   In many-sheeted space-time particles topologically condense at all space-time sheets having projection to given region of space-time so that this option makes sense only near the boundaries of space-time sheet of a given system. Also p-adic phase transition increasing the size of the space-time sheet could take place and the liberated energy would correspond to the reduction of zero point kinetic energy. Particles could be transferred from a portion of magnetic flux tube portion to another one with different value of magnetic field and possibly also of Planck constant h_{eff} so that cyclotron energy would be liberated.

   In the following only the "dropping" option is discussed.

3. The appearance of.1 second time scale characterizing electron and defining a fundamental bio-rhythm is intriguing as is also the appearance of the millisecond time scale defining the time scale of nerve pulses. The hierarchy of Planck constants brings in additional scaling of the time scale by the ratio $r = \hbar/\hbar_0$. If dark protons are involved one could understand all three time scale ranges if r is in the range $10^3 - 10^4$. The TGD based model of EEG [K37] assumes that the preferred values of Planck constant come in powers of 2^{11}, which happens to be near to the proton-electron mass ratio. If the secondary p-adic time scales correspond to those of electron, quarks, and proton inducing basic catalytic steps of the folding then the variation of r in the range $1 - 10^4$ would predict time scale ranges $10^{-7} - 10^{-3}$ s for proton induced folding, $10^{-3} - 10$ s and $.1 - 10^3$ s for electron induced folding.

These very naïve arguments suggest that the general order of magnitude for the folding time might have something to do with the p-adic length scale hypothesis in zero energy ontology.

Should one replace thermal spin glass with 4-D quantum spin glass?

Wolynes models protein as a thermal spin glass. TGD suggests that the entire universe is quantum spin glass. The partition function of spin glass (or rather the average over the partition functions with different coupling strengths between spins) is replaced with vacuum functional, which is exponent of Kähler function. The averaging over the coupling constant strengths corresponds in TGD to the average over so called "zero modes" of the Kähler function: using QFT terms, these degrees of freedom do not couple to the inverse of the propagator defined by the Kähler function. Zero modes characterize the shape and size of the 3-surface and also the classical induced Kähler field on it (classical em field is very closely related to Kähler field) and can be identified as fundamental order parameters in TGD inspired quantum theory of self-organization. In each quantum jump localization in zero modes occurs so that averaging is indeed genuine statistical averaging: quantum states representing the final states of quantum jumps are not de-localized in zero modes.

Evolution at quantum level has selected those proteins for which the rugged "energy landscape" defined by the negative of Kähler function contains only few deep minima. One can criticize the assumption about the selection of the spin glass energy landscape as too strong. There are always deep minima and depending on the initial conditions self-organization leads to some minimum. On the other hand, selection certainly occurs also in the sense that proteins and corresponding spin glass energy landscapes are selected by evolution.

The proposed mechanism might be a general mechanism of evolution. In the generalization of Haken's self-organization theory to quantum TGD context the maxima of the Kähler function correspond to those configurations to which self-organizing system rapidly moves if perturbed. For instance, pattern perception could be described as a dynamical evolution leading to one of few maxima identifiable as "features", which are caricature like patterns providing idealization of the actual sensory stimulus. "Features" would correspond to configurations with one deep minimum of the negative of the Kähler function selected during evolution. Also preferred behavioral modes developed during evolution, "phylogenetic invariants", could have similar identification.

As a matter fact, quantum self-organization should occur even in elementary particle length scales. The duration of elementary particle selves can be estimated from the p-adic length scale hypothesis to be of the order of Compton time determined by the particle mass. Self-organization could explain the selection of preferred p-adic primes characterizing elementary particles and also macroscopic space-time sheets.

Could zero energy ontology and conscious choice be significant factors in the protein folding?

The proposed view about selection of protein conformations is quantal and involves the notion of 4-D spin glass but does not involve zero energy ontology and hierarchy of Planck constants. It was already noticed that the introduction of hierarchy of Planck constants might allow to understand the rough time scales of folding in terms of the secondary p-adic time scales assignable to electron and proton without detailed assumptions about dynamics.

1. In zero energy ontology state function reduction selects one particular folding process rather than a particular folding. The folding process is a sequence of quantum jumps selecting a folding process and then acting on it by U-matrix. The entire folding process including the initial folding is affected in the folding process. The final state is asymptotic self-organization pattern. The asymptotic classical folding process should always lead to the same preferred folding and also begin from the same folding.

2. Fractals are indeed typically fixed sets of iteration and quantum jump sequence is analogous to iteration so that this principle might apply quite generally. By quantum classical correspondence the classical folding should reflect this fractality. The folding process is predicted to have a modular structure with a hierarchy of length and time scales defined by CDs involved. The choice of the folding process would proceed simultaneously in all scales and presumably the fixed point would be reached first in shorter scales so that the folding process would proceed from short to long scales.

3. If the asymptotic classical folding is invariant under the classical folding dynamics, the sequence of quantum jumps leads naturally to a fixed point of the classical folding dynamics in various scales defined by the hierarchy of CDs. Therefore the change of the geometric past and future in quantum jump would be crucial for the understanding of the folding process.

One is also forced to ask whether protein can be treated as a dead matter and whether intentional action preferring the generation of macroscopic quantum coherence (number theoretic negentropy) at various scales could play a role in the folding process. This question whether living matter might behave like living matter might look somewhat strange after few decades but at this moment the historical ballast forces to represent it very cautiously.

10.4.8 Cognitive Evolution As Self-Organization Of Association Sequences

Before the emergence of zero energy ontology cognitive evolution was regarded as a self-organization of association sequences. Association sequences can develop not only the ordinary space-like quantum entanglement but also combine to form longer association sequences having quantum entanglement in time direction. The emergence of association sequences characterized by increasingly larger value of p-adic prime corresponds to the development of larger coherent cognitive units. The formation of association sequences of association sequences corresponds to the formation of cognitive slaving hierarchies. The replication of association sequences provides a geometric realization for the idea of ideas as living organisms.

In zero energy ontology association sequences are replaced with space-time sheets with CDs and the fractal hierarchy of CDs codes for the non-determinism of association sequences. In zero energy property the replication of these states is expected to be easier than in positive energy ontology. This encourages the interpretation in terms of memes. One can assign to these states representations of logic rules in accordance with the idea that physical world forms a cognitive representation for the laws of physics.

10.4.9 Brain As A Self-Organizing Quantum Spin Glass

The plasticity of brain is consistent with the identification of brain as quantum spin glass. In this picture the evolution of sub-selves/mental images is a dissipative self-organization process leading to some asymptotic self-organization patterns which correspond to the valleys of the spin glass energy landscape of brain. One can understand development of memories, habits, skills and even fix idees as a quantum self-organization based on Darwinian selection of sub-selves having nerve pulse patterns and synaptic strengths as neural correlates.

The crucial element of the self-organization is external energy feed making possible interesting self-organization patterns. Nerve pulse pattern is analous to an external energy feed and the propagation of nerve pulse could indeed induce energy transfer inducing self-organization in the cytoplasma just below axonal membrane. The gel-sol phase transition accompanying nerve pulse conduction could define the self-organization pattern induced by the conduction of the nerve pulse along axon. Nerve pulses affect the postsynaptic cell: typically excitation or inhibition is in question. The interpretation is again that the incoming nerve pulses push and pull the postsynaptic cell in different directions in spin glass energy landscape and in this manner cause frustrations typical for spin glass like systems. Also frequency and time codings and the lack of a precise neuronal code are consistent with this.

A flow of cytoplasma and of lipids of cell membrane is induced by the conduction of nerve pulse. If DNA as topological computer model makes sense in the case of axons, this would induce a braiding of the magnetic flux tubes assumed to connect DNA to cell membrane and thus quantum computation and memory representation for the conduction of nerve pulse pattern.

In TGD framework nerve pulse patterns provide a symbolic representation of the sensory experience whereas sensory qualia are located at sensory receptors. The back projection from brain is essential in building the sensory percepts as asymptotic self-organization patterns via the dialog between brain and sensory receptors. Neural pathways would give rise to characteristic self-organization patterns providing symbolic representations for the sensory input. Quantum spin glass paradigm combined with the notion of the geometric memory leads to a general model of long term memories circumventing the basic difficulty of the neural net models of long term memory related to the fact that long term memories identified as synaptic strengths tend to be destroyed by the learning of new memories. This view about memory also resolves the objections against the idea that sensory receptors are loci of sensory qualia.

10.4.10 About The Notion Of Quantum Criticality In TGD Framework

Quantum criticality is a fundamental physical principle of TGD dictating the classical and also quantum dynamics so that it deserves a separate discussion from the "modern" viewpoint inspired by what has happened in TGD during more than decade after writing the text above "classical" view. According to the "classical" view, the value of Kähler coupling strength - the only parameter of theory - is fixed as the analog of critical temperature. In order to characterize the critical degrees of freedom one must say something about the Kähler metric of WCW [K24].

1. The matrix defined by the second order derivatives of Kähler function with respect to WCW coordinates is degenerate as is also the WCW Kähler metric defined by a subset of these derivatives ($G_{K\overline{L}} = \partial_K \partial_{\overline{L}} K$ is the defining formula of Kähler metric in complex coordinates in terms of Kähler function K).

   The reason for the degeneracy is that WCW metric depends on real zero mode coordinates, which do not appear as differentials in the line-element. These coordinate directions of WCW correspond to non-quantum fluctuating classical degrees of freedom not contributing to WCW Kähler metric. The proposed generalization of quantum measurement theory assumes that zero modes are analogous to classical variables defining say the position of a pointer of a measurement instrument and that they are in 1-1 correspondence with the outcomes of quantum measurements in quantum fluctuating degrees of freedom and give rise to quantum classical correspondence.

2. Quantum criticality would corresponds to a situation in which maximum of Kähler function (defining most probable space-time surface in their quantum superposition) corresponds to a Kähler metric for which some elements of Kähler metric approach zero so that the rank for the matrix defined by the non-vanishing components of the Kähler metric is reduced. The resulting degrees of freedom would be effectively zero modes inside the critical manifold but not elsewhere. The criticalities would define an infinite hierarchy analogous to the finite hierarchy of criticalities for finite dimensional catastrophes Thom's catastrophe theory (see `http://tinyurl.com/fpbsm`) [A14]: cusp catastrophe is the simplest non-trivial example.

3. At the level of WCW geometry (see `http://tinyurl.com/ycqyk49f`) conformal symmetry algebras [K109] defining the infinite-dimensional symmetries of TGD Universe - call them with generic name A - this hierarchy could have very elegant representation. The elements of conformal algebra are labeled by integer plus other quantum numbers so that one can write the element of algebra $a_{n,\alpha}$. Critical sub-manifolds woud correspond to sub-spaces of WCW for which the elements $a_{nk,\alpha}$ of sub-algebra A_n (k is integer) annihilate the states or creates zero norm f states from them. Here n is a non-negative integer characterizing the critical manifold. Critical manifolds would be in 1-1 correspondence with non-negative integers n. If n_1 divides n_2, the critical manifold Cr_{n_2} belongs to Cr_{n_1}.

4. In the phase transitions between different critical manifolds some quantum fluctuating degrees of freedom become local zero modes in the sense that their contribution to WCW metric at a given point of WCW vanishes at criticality. Also the reverse transformation can take place.

The progress that has occurred since 2005 raises some interesting questions.

1. Criticalities form a number theoretic hierarchy and primes define “prime criticalities”. Does this mean that the primes dividing integer n define the possible p-adic topologies assignable to criticality defined by n?

2. The hierarchy of effective Planck constants is labelled by integers and giving integer n corresponds to n-furcation made possible by the failure of strict determinism for Kähler action. Could this integer correspond to the integer defining the criticality? Criticality is indeed accompanied by non-determinism realized as long range fluctuations.

3. Causal diamonds have size scales coming as integer multiples of CP_2 scale. Does this integer relate to the integer defining criticality?

4. The condition that the n characterizes finite measurement resolution in the sense A_n annihilates the physical states everywhere would de-localize the critical states outside the critical manifold. Does this mean that also finite measurement resolution is characterized by integer.

5. How the 4-D spin glass degeneracy due to the huge vacuum degeneracy of Kähler action implying breaking of strict determinism relates to quantum criticality?

These suggestive connections suggest that integer arithmetics are coded directly to the hierarchy of criticalities and also be a basic characteristic of consciousness. This would give additional piece of support for the vision about physics as a generalized number theory (see `http://tinyurl.com/y86lo57g`) [K101, K102].

10.5 Could TGD Provide Justification For The Ideas Of Rupert Sheldrake?

Rupert Sheldrake [I88] has developed a theory of learning and memory based on the concepts of morphic fields and morphic resonance. In the following I describe briefly the theory of Sheldrake and consider a TGD variant of of the theory.

10.5.1 Sheldrake's Theory

The following summarizes very briefly the basic ideas of Sheldrake's theory.

1. The basic hypothesis is that learning occurs also at the level of species. If some individuals of the species have learned some habit then it becomes easier for the remaining individuals of the species to learn the same habit. The individuals who learned the habit first need not even live anymore or can live in a distant part of the world. Collective learning is claimed to occur in a morphic resonance analogous to a phase transition leading from a small seed of individuals with new habit to a population having the same habit. Morphic field provides a representation for a habit and resemble the concept of meme in this respect. Sheldrake states the basic assumptions of his theory in the following manner:

   The idea is that there is a kind of memory in nature. Each kind of thing has a collective memory. So, take a squirrel living in New York now. That squirrel is being influenced by all past squirrels. And how that influence moves across time, the collective squirrel-memory both for form and for instincts, is given by the process I call morphic resonance. It's a theory of collective memory throughout nature. What the memory is expressed through are the morphic fields, the fields within and around each organism. The memory processes are due to morphic resonance.

2. Sheldrake defines morphic fields in the following manner:

   Basically, morphic fields are fields of habit, and they've been set up through habits of thought, through habits of activity, and through habits of speech. Most of our culture is habitual, I mean most of our personal life, and most of our cultural life is habitual. We don't invent the English language. We inherit the whole English language with all its habits, its turns of phrase, its usage of words, its structure, its grammar.

   "Alike likes alike" rule states that learning induces learning only in the members of *same* species. This suggests that the morphic fields correlate strongly with genome.

4. Sheldrake represents the learning of language as a good example of morphic resonance.

   Occasionally people invent new words, but basically, once we've assimilated it, it happens automatically. I don't have to think when I'm speaking, reaching for the next word. It just happens, and the same is true about physical skills, like riding a bicycle, or swimming, or skiing if you can ski, these kinds of things. So I think the more often these things happen the easier they become for people to learn. Things like learning language have happened over-well, we don't know how long human language has been around, at least 50, 000 years, so there's a tremendously well-established morphic field for language-speaking. Each particular language has its own field which is usually established over centuries at least.

5. Sheldrake notices also that morphic resonance and morphic fields are not all what is needed to understand evolution.

   The whole idea of morphic resonance is evolutionary, but morphic resonance only gives the repetitions. It doesn't give the creativity. So evolution must involve an interplay of creativity and repetition. Creativity gives new forms, new patterns, new ideas, new art forms. And we don't know where creativity comes from. Is it inspired from above? Welling up from below? Picked up from the air? What? Creativity is a mystery wherever you encounter it, in the human realm, or in the realm of biological evolution, or of cosmic evolution. We know creativity happens. And then what happens is a kind of Darwinian natural selection. Not every good idea survives. Not every new form of art is repeated. Not every new potential instinct is successful. Only the successful ones get repeated. By natural selection and then through repetition they become probable, more habitual.

10.5.2 TGD Based Interpretation Of Morphic Fields And Collective Memory

I have proposed for more than decade ago a TGD based formulation justifying the basic ideas of Sheldrake to some degree. The recent formulation involves several new elements. Zero energy ontology implying that WCW ("world of classical worlds") spinor fields allow an interpretation as memes or morphic fields, the model for living matter in which the notion of magnetic body plays a key role, and the model of DNA as topological quantum computer allowing to identify the morphic quanta relevant for living matter.

WCW spinor fields

In TGD framework zero energy states correspond to the modes of completely classical WCW spinor fields with fermionic second quantization at space-time level having purely geometric interpretation at the level of WCW . The analysis of the degrees of freedom involved demonstrates that WCW spinor fields are analogous to ordinary quantum fields but hav infinite number of components.

1. WCW decomposes to a sub- WCW s association with unions of causal diamonds (CDs). Individual CD is partially characterized by the moduli defined by the positions of its upper and lower tips. The proposal is that the temporal distances between the tips are quantized in octaves of CP_2 time scale and thus coming in good approximation as secondary p-adic time scales for primes very neary to power of two. The most general proposal is that also the position of the upper tip at proper time = constant hyperboloid of future light-cone M^4_+ is quantized for positive energy states. For negative energy states this happens to the

lower tip. This disrete set would provide a discretized quantum version of Robertson-Walker cosmology with discretized lattice like structure replacing the continuum. The interpretation would be that lower tip corresponds to the usual Minkowski space-time of special relativity and the discretized position of upper tip to the space-time of cosmology. This implies very strong predictions such as the quantization of cosmic redshifts which is indeed observed [K93]. Similar quantization would take place in CP_2 degrees of freedom for either tip. WCW spinor fields for single CD would depend on these moduli and for positive (negative) states one would have wave functions in the space formed by sub- WCW s with wave function basis consisting of products of plane waves in M^4 with a wave function in the discrete subset of $M^4_\pm$. These degrees of freedom generalize those of a quantum field in Minkowski space.

2. The notion of generalized imbdding space forces to assign to a given CD a selection of quantization axis of energy and spin which in the case of M^4 boils down to a choice of a preferred plane $M^2 \subset M^4$ plus a choice of time direction (rest system). In the case of CP_2 the choice of quantization axes of color isospin and hypercharge means a choice of a homologically trivial geodesic sphere of CP_2 plus preferred isospin quantization axes. The space for possible choices of quantization axis defines additional moduli. The selection of quantization axes in state function reduction means a localization in these degrees of freedom. The space characterizing the selections of color quantization axis represents an example of so called flag manifold. It has already earlier appeared in TGD inspired biology with a motivation coming from the observation of topologists Barbara Shipman that the mathematical model for honeybee dance leads naturally to the introduction of this space. Shipman speculated that quarks have some role in biology [A7]. Dark matter hierarchy indeed makes indeed possible scaled up copies of QCD type theory in biological length scales.

3. WCW spinor fields restricted to a CD with fixed moduli have infinite number of bosonic and fermionic degrees of freedom. Spin-like degrees of freedom for these fields correspond to WCW spinors, which describe many-fermion states consisting of quarks and leptons and bosons defined as their bound states. This Fock state is assigned to each 3-surface and the dependence on 3-surface defines purely bosonic ("orbital") degrees of freedom, which can be coded by using a state basis whose elements have well-defined spin and color quantum numbers. The bosonic and fermionic degrees of freedom are super-symmetrically related.

WCW spinor fields as morphic fields

The interpretation of the WCW spinor fields as memes or morphic fields is encouraged by two observations.

1. Zero energy states have an interpretation as Boolean rules $A \to B$ as well as self-organization patterns. Fermion number 1 and 0 for a given fermion mode represents values of one particular Boolean statement in positive *resp.* negative part of the state. The instances of A are assigned to the positive energy (initial) state and those of B to the negative energy (final) state and the quantum superposition of the paired instances defines the rule. Since time-like entanglement coefficients define M-matrix, the interpretation as a law of physics coded to the structure of the physical state itself is possible. Fermionic degrees of freedom correspond to the spin indices of WCW spinor fields. Besides this there are "orbital" degrees of freedom in the moduli space for CDs and in the space of deformations of light-like 3-surfaces. It is natural to assign these degrees of freedom to sensory perception.

2. The p-adic description of cognitional action involves a generalization of the notions of number and of embedding space. The hierarchy of Planck constants means a further generalization of the notion of embedding space by replacing it with a book like structure. It seems that the discrete intersection of real and p-adic space-time surfaces consisting of rational points (possibly also algebraic points) is crucial from the point of view of consciousness theory. This is true also for the intersection of real and p-adic variants of WCW identified as 3-surfaces whose mathematical representation makes sense in both real and p-adic number fields in preferred coordinate fixed by symmetries.

   The first intersection is expected to be relevant at quantum field theory limit, which involves the replacement of the partonic 2-surfaces with a discrete subset of points carrying quantum numbers. The second intersection is relevant in the full quantum theory. The notion of number theoretic Shannon entropy having negative values makes sense in both intersections since entanglement probabilities must make sense in both number fields so that they are rational or belong to an algebraic extension of rationals. In these intersections of realities and various p-adicities the evolution of memes is expected to take place.

One manner to understand the special role of rationals and algebraics relies on the observation that rationals represent islands of order in the sea of chaos defined by reals since their pinary expansion is predictable and analogous to a periodic orbit of a dynamical system whereas for a generic real number there is no manner to predict the pinary expansion.

Morphic fields relevant to living matter

All zero energy states have interpretation as memes or quanta of morphic fields in TGD framework. One can however ask what zero energy states are relevant for biological systems.

1. The memes relevant to living matter must have a very concrete connection to biology. DNA as topological quantum computer hypothesis states the magnetic flux tubes connecting nucleotides to lipids of nuclear and cell membranes define braid strands needed to realize topological quantum computations. Nerve pulse patterns induce fluid flows of cytoplasma and of lipids in turn inducing time-like braidings defining running topological quantum computation programs and their memory representations as space-like braidings in the final state. These programs living (in very literal sense) in the brains of geometric future and past define a 4-D population of memes. The intronic part of the genome is specialized to topological quantum computations and the time scale in this case can be and must be faster than for the chemical gene expression. The repetitive character of many intronic DNA sequences regarded as evidence for their junk character does not mean any restriction for topological quantum computation.

2. The notion of magnetic body has a central role in TGD inspired biology. Magnetic body has an onion-like fractal structure and astrophysical size with wavelength of EEG wave defining the size scale of the magnetic body with which it is associated. Magnetic body acts as as an intentional agent using biological body as a motor instrument and sensory receptor. Magnetic body receives sensory and other information from biological body through EEG and its fractal counterparts and controls biological body via EEG type signals sent to the genome, where they induce chemical or electromagnetic gene expression. This allows to imagine also a mechanism of collective learning. The spatio-temporal nerve pulse patterns defining topological quantum computations are mediated via EEG and its fractal counterparts to the magnetic body of organism and from it to the magnetic body of another organism. The magnetic body of Earth - magnetic Mother Gaia- could serve as a relay station and Schumann resonances and alpha band could allow broadcasting of the nerve pulse pattern to a large number of magnetic bodies of organisms. From the latter magnetic body the field representation of nerve pulse pattern would induce via EEG type signal from magnetic body to the receiver genome the original nerve pulse pattern in the brain of the receiver. Nerve pulse patterns would be quite generally induced by magnetic bodies via appropriate part of the intronic genome as electromagnetic gene expression. This mechanism could be also involved with telepathy and remote mental interactions.

3. Morphic resonance and alike likes alike rule can be understood from the condition that the intronic parts of genomes must be similar enough to allow the realization of the topological quantum computation. Also neuronal pathways involved must resemble each other in order that spatial nerve pulse patterns can be re-produced faithfully enough. Also the evolutionary levels must be more or less the same in order that the topological quantum computation has same meaning for the receiver and sender. Therefore the collective memory might be restricted to the level of species. This might be however too strong an assumption. For instance, shamanism could represent an example of interspecies memory. The TGD based view about memory allows also the possibility to use the memories of the already deceased members of species which can in principle continue to exist in the geometric past.

4. The general vision about evolution as recreation of the quantum Universe implies that creativity is in very literal sense a basic aspect of TGD Universe. The U process represents the creative aspect of consciousness generating quantum super-position of Universes from which generalized state function reduction process selects the outcome. Both volitional actions and sensory perception involves the selection but quantum statistical determinism implies that sensory percepts are usually predictable.

Collective memory, geometric memory and self hierarchy

The notion of species memory is rather radical departure from the teachings of standard neuroscience so that TGD based view about memory deserves a separate discussion.

TGD predicts infinite hierarchy of selves and if this hierarchy has levels between living systems and entire universe, the idea about collective memory makes sense and generalizes to an entire hierarchy of them.

Geometric memory provides a promising candidate for the mechanism of a long term memory. Geometric memory is made possible by the fact that self can have multitime experiences such that the space-time sheets associated with various values of the geometric time give contributions to the experiences and past contributions are experienced as memories. In zero energy ontology these space-time sheets are associated with sub-CDs of CD associated with self. Both time-like entanglement between sub-CDs of recent and past implying sharing and fusion of mental images an classical communications between these CDs are possible and give rise to episodal memories (direct re-experiences) and symbolic memories.

Since both geometric past and future change in each quantum jump these memories are not stable: long term memories are certainly unreliable. The memory formation mechanism of brain however tends to stabilize these memories. There is in principle no upper bound for the span of the geometric memories and one can consider the possibility of racial memory and even species memory. Under suitable conditions organism could be able to have the space-time sheets of the geometric past as its sub-selves and experiences these memories. Thus geometric memory is consistent with Sheldrake's claims and to some degree supports them.

Language learning and morphic resonance

The easiness of children to learn language could have explanation in terms of morphic resonance. The strong quantum entanglement between the child and parents, especially mother, could make the morphic resonance possible in the proposed sense. One can even imagine that mother's magnetic body directly induces nerve pulse sequences representing linguistic memes in the brain of child.

One can of course wonder why it is so difficult for the older people to learn language. Do we force us to learn the language at reflective level although it could occur at proto-level also. Older people learn rules but find difficult to apply them whereas child learns to apply the rules without learning the rules themselves. Are older people so far from quantum criticality that the large fluctuations leading to the generation of the new level of self-organization are not possible anymore? The reason could also relate to the degeneration of the magnetic flux tubes circuits due to ageing so that new topological quantum computation programs are not establishes so easily anymore.

Self hierarchy, bio-feedback and sociofeedback

Magnetic bodies act as intentional agents in the proposed model. They form also a hierarchy analogous to master-slave hierarchy. The proposed mechanism of collective learning involves the magnetic body of Earth in an essential manner. Also magnetic bodies of larger structures could be involved: there is indeed evidence that remote cognition involves galactic magnetic fields [K83] , [J50].

The phenomenon of bio-feedback provides direct evidence for this phenomenon in a length scale familiar to us. By monitoring the behavior of say single neuron, it is possible to learn to affect the behavior of neuron volitionally. No knowledge about how this happens is needed: the volition is enough. The explanation would be that the information provided by the monitoring goes to the magnetic body of the person which reacts by sending control signals to the brain. The already existing magnetic flux tube connections guarantee that the volitional act affects the neuron. The possibility of biofeedback suggests the possibility of socio-feedback and feedback even at the level of species and entire biosphere.

An interesting test for the idea that people very close to each other could directly affect the brain function of each other would be biofeedback in which subject person tries to affect the behavior of a neuron of a close friend or relative. Mother and child might be an optimal choice in this respect.

10.6 Sheldrake's Morphic Fields And TGD View About Quantum Biology

I received two books of Rubert Sheldrake as a gift from Mark McWilliams, who has for years helped me by reporting about problems at my homepage and sending links to interesting articles. The titles of the books of Sheldrake are "*A new Science of Life: the Hypothesis of Formative Causation*" [I88] and "*The Presence of the Past: Morphic Resonance and Habits of Nature* " [I89]. The titles reveal the two basic notions underlying the vision of Sheldrake.

What makes the study of the books so rewarding is that Sheldrake starts from problems of the existing paradigm, analyzes them thoroughly, and proposes solutions in the framework provided by his vision. There is no need to accept Sheldrake's views, just the reading of his arguments teaches a lot about the fundamental ideas and dogmas underlying recent day biology and forces the reader to realize how little we really know - not only about biology but even about so called established areas of physics such as condensed matter physics. These books are precious gems for anyone trying to build overall view.

The discussion of the previous section is several years older than the discussion of this section and I have not checked whether the two views are consistent and whether I am repeating same statements. This is not solely due to my laziness: the me of year 2004 is not the me of year 2011 and I feel that it is useful to allow the two prophets to express themselves freely: the reader can use both inputs besides Sheldrake's own excellent representations to form her own views. The reader should take these sections as jazz improvizations using the same theme rather than expressions of last will.

10.6.1 Habits Of Nature

The idea that Nature would have habits just as we do is probably one of those aspects which generate most irritation in physicalists believing that Nature is governed by deterministic laws with classical determinism replaced with quantum statistical determinism. Sheldrake is one of those very few scientists able to see the reality rather than only the model of reality. Morphic resonance would make possible to establish the habits of Nature and the past would determine to high extent the present but on organic manner and in totally different sense as in the world of physicalist.

Some problems of biology

It is instructive to consider as an example the first chapter of the book about formative causation discussing the basic problems of biology. Shelrake's proposal is that something more than organic chemistry is needed to understand living systems. He assigns to this something the notions of formative causation, morphic fields, and morphic resonance. In the following brief summary I refer also to some TGD inspired proposals for the needed new notions as remarks.

1. First Sheldrake discusses first the standard mechanistic view which does not accept any "vital factors" or goal directedness but just the blind chemistry based on random change and choice but implicitly brings in these factors as genetic programs. In neuroscience one introduces computer paradigm without realizing that computers by definition are systems whose goal is to solve a problem mechanically. The goal is of course not posed by the computer but by its builder. One important aspect of the vision is the idea about chemically operated switches (they could be non-coding DNA sequences) switching genes on and off. Morphogenesis could

be seen as differentiation in which genes are switched on and off to produce a particular body part. A fairy tale in which the hero receives a key to open the next door to receive a new key to open... is very attractive metaphor for morphogenesis as a chemical process. This idea is very powerful but might not be all that is needed. The question popping up automatically is "Who turns the switches on and off?".

Note that assigning the information about organism to its genome is very near to the idea about organism as hologram. More generally, the idea about germ cell as a hologram representing some essential aspects about the organism is very attractive. There would no need to assign this information to genes or DNA alone. This would be more refined form of the naïve idea that there is some kind of miniature representation of the fully developed organism realized in germ cells level.

2. Sheldrake discusses four problems of morphogenesis.

   (a) The first problem of morphogenesis is its stability - one speaks about regulation. In some experiments second cell of two-celled embryo is destroyed but the embryo still develops to a full organism albeit with abnormally small size. One can also fuse several embryos and they develop to single abnormally large organism. This suggests goal directedness. In the fairy tale the hero must overcome all kinds of misfortunes while trying to find the door to which the newest key fits.

   Development as a self-organization process depending only weakly on initial conditions might help to understand goal directedness as something only apparent. The basic aspect of self-organization indeed is the weak dependence on initial values: the reason is that dissipation in presence of external energy feed leads to a highly unique outcome. In absence of energy feed all motion ceases! Note however that the notion of self-organization should be also defined precisely. Should we adopt a purely classical view about self-organization based on non-equilibrium thermodynamics or about its quantum counterpart?

   (b) Second problem is how completely new structures (eyes, heart, brain, body parts, ...) emerge during morphogenesis. It is very difficult to understand this in terms of genetic code alone. Genes seem to be too rigid structures. In the vision of Sheldrake's (and TGD vision) genes are only the hardware. Also software is needed. The fairy tale about hero with the keys comes in mind. Maybe the keys would be represented by the genes serving as switches activating or de-activating genes? This could mean a highly flexible chemical program since each reaction could proceed only when the preceding reactions have proceeded.

   But is morphogenesis only a realization of an existing plan or a genuinely creative process? What happens when something genuine new emerges in the genuine evolutionary process leading to full grown organism? Could non-equilibrium thermodynamics help to conceptualize the situation? In non-equilibrium thermodynamics one has several flow equilibria and the emergence of something genuinely might be seen as emergence of a new flow equilibrium. But is non-equilibrium thermodynamics enough? Is quantum coherence in biological length scales necessary in order to understand the creative aspects of morphogenesis.

   (c) Regeneration is the third problem. Full grown organism is able to regenerate large damaged parts of the organism. Also small pieces of organism can develop to a full organism. The brain of salamander can be split into pieces and these pieces can be shuffled randomly: yet the development leads to a salamander with a healthy brain. Could one regard organisms as hologram like structures with pieces of organisms representing in a good approximation the entire organism?

   The recent discoveries showing that the amount of DNA does not correlate much with the evolutionary level force to conclude that DNA alone cannot code for the entire organism. So called homeobox genes thought originally to code the phenotype of the organism are essentially same for all organisms so that something else is definitely involved. Could genetic code combined with self-organization and hologram paradigms be enough? The answer depends much about what we mean with self-organization and with hologram.

Or should one interpret DNA as hardware and assume software as something unknown to the recent day physics?

(d) Reproduction is the fourth problem. It is also clear that a kind of fractal pattern is involved in the sense that the reproduction is scaled up variant of DNA replication and induced by the replication. The idea that everything reduces to DNA replication is attractive but do we really understand DNA replication at the level of first principles? Could it be that replication in some sense reduces to some fundamental process of Nature not yet identified in what we are used to call fundamental physics? Sheldrake suggests that morphic resonance favors the formation of almost copies and therefore replication. Morphic resonance is analogous to the tuning of radio but why this tuning should take place spontaneously? What principle could imply it?

Remark: In TGD framework the notion of generalized Feynman diagram leads to the idea that replication is indeed a key aspect of quantum physics. The 1-D lines of ordinary Feynman diagrams are replaced by 3-D light-like surfaces identifiable as orbits of partonic 2-surfaces. These 2-surfaces can have arbitrarily large sizes and one could assign them even to cell membrane. By strong form of holography these 2-surfaces are very much like holograms representing 4-D physics almost faithfully (the precise characterization of "almost" would require a more technical language telling not much for a non-mathematician). In the vertices of generalized Feynman diagrams the ends of the light-like 3-surfaces are glued together along partonic 2-surfaces. The simplest $1 \rightarrow 2$ vertex representing particle decay or emission has interpretation as a replication of partonic 2-surface. The quantum states associated with the resulting partonic 2-surfaces are not identical but geometrically replication is in question.

Could one identify this process as the fundamental replication process? If so, then replication in living matter would be only special case of a universal process present already in particle physics and distinguished from it only by the enormous complexity involved. This would be of course only the fundamental mechanism of replication. One must also explain why replication occurs.

The idea about self-tuning is highly attractive as a partial explanation for why replication takes place. What tuning makes possible is information transfer and in TGD framework there is temptation to explain tuning in terms of Negentropy Maximization Principle (NMP) [K59].

3. The understanding of morphogenesis is difficult but should be child's play as compared to the understanding of behavior. Inherited behavioral patterns - instincts- define the first hard problem. Information is transferred between generations and saying that genes -that is organic chemistry- code this information does not help much. Second problem is the goal directnedness of the animal behavior: animals can modify their behavior when something prevents the achievement of the goal. Behavior can be also intelligent: animals can learn new behavioral patterns. This is not in accordance with the idea that behavior is hardwired in the genome.

Remark: Physicist might see behavioral patterns as 4-dimensional patterns resulting in self-organization: characteristic time evolutions. But does this kind of notion make sense? Does it assume additional time? Usually it is thought that self-organization corresponds to an evolution of a 3-D pattern rather than 4-D one. Perhaps TGD based view about time is needed. The experienced/subjective time is assigned to conscious experience identified as a sequence of quantum jumps defining the basic building brick of conscious existence. Subjective time is not identified with the geometric time although they relate closely to each other- at least in standard wake-up consciousness [K10].

Each quantum jump replaces 4-dimensional pattern with a new one and the self-organization patterns in this 4-D sense could correspond to behavioral patterns whereas approximately static 4-D patterns reducing to 3-D patterns would represent morphologies. There are quantum jumps within quantum jumps so that the outcome is a fractal pattern having also interpretation as a self hierarchy. This gives one possible meaning for the "presence of the past" in the title of the second book of Sheldrake. Living matter would be essentially 4-dimensional and the goal directed behavior based on memory would reflect this 4-dimensionality: goal in general case 4-D pattern. In zero energy ontology the arrow of geometric time need not be always the same and signals propagating to geometric past are key element of TGD based view about memory, intentional action, and metabolism [K10]. This would represent a new element distinguishing TGD view from Sheldrake's view.

4. The notion of evolution is also problematic. Can microevolution within species explain the evolution of species itself? Or do sudden discontinuous jumps take place? Could evolution involve a genuinely creative aspect? Is there any hope that a choice among random mutations could explain the emergence of a new highly organized morphological or behavioral pattern? Note that exactly the same problem was encountered at the level of morphogenesis and development of individual. Only the time scale is different.

   Also adaptive convergence looks mysterious: same structure emerges at different sides of Earth simultaneously. For instance, the emergence of large primates leading to humans took place at widely separated places. This forces to ask whether morphic fields are involved and make entire species an organism so that the evolution is non-local process. This also relates to the idea about bio-system as a hologram. In Sheldrake's vision the simultaneous emergence of new species would reflect the holistic evolution of the entire biosphere.

   Remark: In TGD framework the emergence of a completely new structure could involve a phase transition introducing a new level to the hierarchy of Planck constants assignable to a given species. Since the value of Planck constant serves as a measure for evolutionary level, something genuinely new would emerge in the process. The maximal value of Planck constant could allow to characterize the evolutionary level of cell or neuron, organ, organism, population, and even species. The understanding of dark matter would become a prerequisite for the understanding of the living matter.

5. Sheldrake discusses also the origin of minds and parapsychology in this chapter. Morphic fields could obviously relate to mind and make also possible remote mental interactions.

   Remark: In TGD framework the theory of living matter involves quantum theory of consciousness as an essential part and the notion of magnetic body carrying dark matter - in particular dark photons- is a good candidate for the counterpart for the morphic fields.

The notion of morphic field

The notions of morphic field, morphic resonance and formative causation are very interesting and there is considerable support for Sheldrake's vision. The initial motivation for the notion of morphic field was that the same skill discovered by populations located in different parts of the world. Theory leads to idea about learning and memory at the level of species and also to an idea about gene expression at level of species in which remote activation of genome takes place using morphic signals from past. Genome would be the hardware and morphic fields the software.

Shelrake uses TV as an analogy.

1. Morphic fields would be analogous to radio waves carrying information (say in terms of amplitude or frequency modulation) and could code genetic information and genetic programs. Genes act as antennas and the details of gene expression depend on the value of the tunable antenna frequency. When the antenna frequency changes, the received signal changes and gene expression changes too. Adaptation could correspond to a change of antenna frequency in turn modifying gene expression as a response to a modified morphic signal. Also epigenetic inheritance could relate to the activation of genes acting as switches for genes. Mutations would correspond to changes in the genome analogous to the changes in the hardware of TV.

2. The tuning to some frequency would be the basic process in brain and is known as entrainment. In fact, even mechanical systems such as clocks are known to entrain to a common rhythm. The physical mechanism for this is not well-understood. Perhaps the entrainment is a fundamental physical process having explanation in terms of NMP (Negentropy Maximization Principle [K59]. If so, the idea about tuning would be a generalization of what we already know to take place.

3. The idea about morphic signals from past affecting the gene expression in the genomes of the same species would explain many strange findings discussed by Sheldrake. Morphic signals could silence or activate genes. If there are genes inducing modifications of DNA, then morphic signals could even modify the genome. Species would be kind of hologram: each member would be a representation for the species and genetic expression would be collectively determined.

4. What kind of morphic field patterns are possible? A natural proposal is that DNA sequences can be coded to the spatiotemporal patterns of morphic fields. TGD based realization of morphic fields is one possible realization of his condition. In this case frequency which for a fixed photon energy is coded by the value of Planck constant matters as also the connection defined by magnetic flux tube between molecules involved.

   Modern radio-communications code the data to bit sequences represented as temporal patterns of the radio wave. Could the temporal patterns of morphic fields be important and could one imagine some codes? Among other words this would make possible selective communications using passwords. For resonance common antenna frequency would be enough and the experience from computer communications suggests the possibility of a coding based on the representation of bits as pulses but many other codes can be imagined.

   Remark: If certain carrier frequencies carry information, NMP would explain why self-tuning occurs.

Sheldrake proposes speculative but fascinating applications of morphic resonance in somewhat unexpected contexts.

1. The fact is that even the formation of simplest crystals is poorly understood for the simple reason that the calculations needed are extremely complex. Simplified models represent larger numbers of crystal structures and it is difficult to understand why only very few crystal forms are realized in Nature. The standard professional folklore among chemists is that once some new chemical compound has been been crystallized for the first time its crystallization becomes gradually easier and easier. The obvious looking explanation for this is not however obvious. Could morphic fields select one of the many possible crystal forms? Could crystallization to a specific crystal form be a habit of Nature?

2. Protein folding is second mysterious phenomenon. The mysterious aspect of the process are its deterministic character and its rapidity. The number of possible foldings is astrophysical and one can expect a huge number of local minima of free energy and therefore a huge number of thermodynamically stable foldings. Sheldrake suggests that the interaction with the morphic fields of the environment is part of the process and makes the folding a learned habit.

Inheritance and morphic fields

Sheldrake discusses inheritance and suggests that besides genetic inheritance and epigenetic inheritance also morphic fields could give rise to a new kind of heritance. The basic question is whether the acquired characteristics resulting from adaptation could be inherited in some manner. This is usually known as Lamarkcian inheritance of acquired characteristics. One can also ask whether adaptations perhaps allowing interpretation as mutations of morphic fields- software- could be transformed to mutations - modifications of the hardware.

1. Epigenetics (see `http://tinyurl.com/4xpwcm`) [I6] is the study of the mechanisms inducing changes in gene expression without change in DNA itself. Differentiation of cells is the most obvious example of this kind of process. The suppression of gene expression without altering the DNA sequence of altered genes by DNA methylation or histone deacetylation is one mechanism of epigenesis. Epigenetic changes are preserved in cell division.

   Also epigenetic inheritance is possible. This requires that the modification of genes -say methylation of DNA - takes place also at the level of eggs and sperm. For instance, it has been discovered that the effects of famine and diseases can echo to the next generations. The mechanism making this possible is not well-understood and one can ask whether morphic resonance is involved and affects also the eggs and sperm. If so, one could speak about inheritance of acquired characteristics.

2. The notions of dominating and recessive gene (see `http://tinyurl.com/aqvyae`) are familiar for everyone from school days but very few of us has asked what makes the gene dominant or recessive. Or whether both genes (alleles) could affect the phenotype (say color of the flower) to some degree. Usually the chromosomes appear as non-identical pairs and the members contain corresponding genes (alleles) coming from the parents. These genes are not identical so that they can code different trait for the same phenotype. The question is what chooses which allele is expressed. The usual answer is that the "normal" gene is expressed. But what makes the gene "normal" ?

   The proposal of Sheldrake is that morphic signals from past force the expression of the normal gene. The normal gene is the one expressed also in the past and for these reason the signal from past supporting the expression of this gene dominates. Gene expression is to some degree like a habit due to majority democratic decision of a 4-D society. It is also possible that both alleles determine the trait. Sheldrake's interpretation would be that in this case both morphic signals can be realized and the outcome is a mixture of traits. Different cells have in this case different habits.

3. Sheldrake discusses also what is known as genetic assimilation discovered by Waddington in his study of fruit files. Fruit flies are subjected to external stimuli and as a result develop abnormal phenotypes. What happens that when external stimuli are absent the abnormal phenotype still appears. One can consider several explanations.

   (a) Waddington explains this in terms of canalized pathways of development which he calls chreodes. Abnormal chreodes would be so stable that the absence of stimulus originally inducing them would not affect the situation.

       Remark: In TGD framework chreods could correspond to 4-D self-organization patterns depending only weakly on the initial conditions.

   (b) Epigenetic inheritance could explain the phenomenon.

   (c) Also morphic resonance could explain the finding. The morphic signals from previous generations are present and the net signal would favor the continuation of abnormal gene expression. Indeed, Mae-Wan Ho demonstrated that a strain of flies not subjected to the treatment at all also exhibited the abnormal phenotype in absence of the stimuli. Gradually however the normal phenotype wins. Morphic resonance explains this finding whereas epigenetic inheritance fails to do it.

4. Adaptation to an external stimulus (such as X-rays, come chemical, unusual temperature....) can produce similar effects on phenotype as a genuine homeotic mutation (say the replacement of antenna of fruit fly with wing). Why mutations can produce effects similar to those produced by adaptation? Is it possible that adaptive changes are transformed to mutations by some mechanism?

   (a) Epigenesis is a possible explanation for the change of the phenotype. Epigenetic inheritance does not however explain whyt mutations and adaptations look so similar.

   (b) Morphic resonance would modify only the software but not hardware and could thus explain adaptation. The modification of the antenna frequencies of genes could have profound effects on gene expression in the case that the antenna frequencies of the switch genes are modified. Morphic signal could be even turned off or on.

Neither explanation for adaptation is able to explain why mutation and adaptation produce similar modifications of the phenotype nor provide a mechanism transforming long term adaptation transform to a mutation. In the case of adaptation the same effect would be produced by using suitable genetic program. Does the finding of the correct genetic modification - addition of a new gene in the simplest case- require trial and error process? How the system knows what mutation produces the same effect as the more complex genetic pathway induced by adaptation? How the activation of this pathway could favor the selection of mutated genes producing the same effect? The Darwinian answer to the question would be of course "survival of the fittest" but is this process too slow?

Remark: Later a TGD inspired mechanism for the transformation of adaptation to mutation will be discussed.

10.6.2 TGD Inspired Quantum Biology

TGD inspired quantum biology leads to a picture which has quite a lot in common with Sheldrake's vision. The hypothesis are following.

1. There is a hierarchy of conscious entities and therefore also what can be called hierarchy of collective levels of consciousness. One can speak about species as a living and conscious organism. This suggests among other things coherent collective gene expression and one ends up with the notions of super genome assignable to organs and hyper genomes assignable to organisms, populations and even species. Entire biosphere can be seen as conscious living organism.

2. TGD is an attempt to unify real number based physics and p-adic physics for various p-adic number fields interpreted as physical correlates of cognition. One can assign to each p-adic prime a number theoretic entropy making sense when probabilities are rational or even algebraic numbers. The number theoretic entropy can have negative sign and in this case represents genuine information. In the case of negentropic entanglement the interpretation is that entanglement represents information. This information is not about the state of individual subsystem but about the state of the entire entangled system. A kind of abstraction representing a rule with paired states in the superposition representing the instances of the rule.

   The proposal is that living systems reside in well-defined sense in the intersection of real and p-adic worlds: in the intersection of matter and cognition. Combined with negentropy maximization principle (NMP) stating the information contents of conscious experience is maximal [K59] this leads to a more general view about quantum jump and state function reduction: state function reduction need not anymore be a random process. NMP could explain why morphic resonance identified as tuning to particular frequencies takes place spontaneously.

3. Non-locality is essential. TGD provides a new view about fields and the relationship between experienced and physicist's time. One outcome is possibility of macroscopic quantum entanglement and also time-like entanglement in macro-temporal scales of order of memory span and time scale of planned action. One can say that any physical system is four-dimensional and for the understanding of living system this four-dimensionality is essential.

4. The identification of dark matter (the dominant portion of matter) as ordinary matter but with (effective) Planck constant equal to integer multiple of and hence larger than ordinary Planck constant, is essential. For large values of Planck constant macroscopic quantum phases are possible even in the scales of order Earth size and would be a crucial element of living matter making among other things quantum entanglement in the scale of species possible. One can indeed imagine the possibility of collective gene expression. Also phase transitions changing the value of Planck constant would play a key role in bio-chemistry. Dark matter indeed plays a key role in the TGD inspired model for living systems.

5. So called topological quantization of classical fields is essential. In particular, magnetic fields correspond to flux quanta which have concrete geometric representations as flux tubes and sheets identifiable as non-trivial topology of space-time in macro scales.

   (a) The notion of magnetic body is in a key role. One can say that magnetic body uses biological body as a motor instrument and sensory receptor. A fractal hierarchy of EEG like radiation patterns makes possible control by magnetic body and communication to it from biological body. Topological field quanta- in particular magnetic body carrying dark matter- plus ordinary inanimate matter make together living matter.

(b) Also classical electric fields are predicted to be important: living matter is indeed full of electrets. One can consider two kinds of electric fields. In the first case one can have strong electromagnetic (electro-weak) fields although space-time sheet is almost vacuum extremal. In the second case one has far from vacuum extremal and electromagnetic field and color gauge field are proportional to each other. Both situations are expected to be important in biology [K41, K37].

(c) So called topological light rays ("massless extremals") attached to magnetic flux tubes are in central role [K70]. Topologically condensed dark photons propagate along them and they can be regarded as analogs of laser beams making possible precisely target communications without dispersion and with maximal signal velocity.

6. Morphic fields might allow identification as dark photon signals propagating with light velocity: this implies effective simultaneity. Also genuine simultaneity is possible by quantum entanglement in macroscopic scales. I have proposed a model for remote DNA replication and remote gene expression and even remote modification of genome becomes possible if there are genes specialized to this.

   DNA and also other biomolecules act as quantum antennas receiving and sending "dark" photons. Two molecules communicate and are able to interact when they have same antenna frequency. This is key part of also bio-catalysis and quantum antenna resonance makes it possible for biomolecules to find each other in the dense soup of biomolecules.

7. Genetic code generalizes and has several realizations. One can say that DNA sequences provide names for polar molecules and one can imagine a mechanism which assigns to this kind of molecule a DNA sequence which codes for a protein attaching to this polar molecule. This might be the basic mechanism allowing the immune system to modify itself rapidly as a response to external stimuli such as invader molecules.

The TGD counterparts of morphic fields

Sheldrake does not speak about quantum effects but is well aware that new physics is needed to understand morphic fields. It is indeed clear that one cannot understand morphic fields in standard physics framework. Even standard quantum theory might not be enough since it allows quantum coherence only in atomic and molecular length scales and already now it is known that quantum coherence prevails in longer length scales in living matter.

1. Quite generally, the ordinary classical gauge fields allowing geometrization in TGD framework and their quanta would define could candidates for the counterparts of morphic fields. This would include both electro-weak and color gauge fields and for large values of Planck constants both weak and color gauge fields could have interaction range relevant for living matter. Biomolecules would act as quantum antennas and morphic resonance would correspond to antenna resonance.

2. Magnetic flux tubes carrying dark photons would replace morphic fields. The braiding of magnetic flux tubes would make possible coding of topological quantum computer programs and flux tubes could connect various molecules with same resonance frequencies making them quantum antennas. The changes of Planck constant for the flux tubes would change their lengths and the contraction of the flux tube could bring distant molecules near to each other so that they would participate in common reaction. This would be the basic mechanism of DNA replication, DNA-mRNA transcription, mRNA-amino-acid transcription and other similar processes. One can also imagine remote replication of DNA and remote version of gene expression. Here TGD based view about dark matter predicting that the states of dark nucleons are in 1-1 correspondence with DNA, RNA, tRNA, and amino-acids is of crucial importance since it makes possible for water to realize genetic code so that biological realization would emerge from this more fundamental realization.

3. The fractal hierarchy of magnetic bodies makes possible collective quantum coherent gene expression and perhaps even collective modifications of genome explaining the convergent evolution. One can imagine that the flux sheets traversing through DNA arrange it to flux

sheets organizing the DNAs of organs to single coherent whole. Same would apply in the case of organism and perhaps even in the case of group of organisms and of population. I have introduced the notions of super - and hyper genome to describe this idea [K43].

It must be emphasized that the TGD counterpart for morphic fields and morphic resonance would not explain the creative aspects of evolution. Also the TGD based view about quantum jump, zero energy ontology, hierarchy of Planck constants, NMP, and other new notions are needed.

Self-organization and morphic resonance

Consider next the general TGD inspired view about self-organization by the analog of morphic resonance.

1. In TGD Universe one could see morphologies as 3-D static self-organization patterns and behavioral patterns as 4-D self-organization patterns. The signals defined by morphic fields should select these self-organization patterns. Since self-organization patterns typically depend only weakly on their initial values (now basically 4-D self-organization patterns replaced by new ones in quantum jumps), morphic fields must select initial values properly. In 4-D situation about which static 3-D situation is special case, frequencies and wave lengths would represent simplest information about the asymptotic self-organization pattern. They would correspond to higher level slowly varying fields serving as effectively external parameters determining the self-organization patterns in shorter time and length scales in accordance with the Slaving Principle of Haken.

2. One can also imagine the morphic resonance mechanism in which molecules act as quantum antennas tuning to each other and forming interacting groups of molecules. The ability of biomolecules to find each other in a dense soup of biomolecules could be based on pre-existing flux tube connections between them. Morphic resonance could be seen as spontaneous self tuning. Organisms would be like radio receivers spontaneously tuning to frequencies at which the previous generations send information. After this tuning the self-organization would proceed rapidly. In terms of consciousness theory one might say that self at the higher level of hierarchy would turn its sub-selves like we tune radio to a particular wavelength.

   But why this tuning would take place spontaneously? One can argue that tuning generates negentropy and in TGD framework the basic distinction between living and inanimate is negentropy. Could the NMP - in some sufficiently strong form- explain why this tuning takes place? What the maximization of the information content of conscious experience [K59] can mean is however not clear. NMP could also relate to how the arrow of geometric time emerges and in sufficiently general form could even explain why the contents of sensory experience is about rather narrow time interval (with duration of about.1 seconds for human sensory perception) [K10].

   Tuning to the frequencies or morphic fields realized as antenna frequencies would be the manner to determine in a given scale the initial conditions leading to unique final outcome very rapidly. The hierarchy of Planck constants assignable to flux tubes mediating dark photons signals would allow the dark photons to have same energy -say at visible range- but different wave-length to which flux tube would be proportional to. Kind of Indra's web would serve as space-time correlate for the morphic fields.

   Tuning to a particular frequency to maximize conscious information suggests that this particular frequency defines a carrier wave for information transfer. Frequency and amplitude modulations and bit sequences represented as temporal patterns is what comes first in mind as concrete representations of this information. TGD based view about hearing [K41, K81] suggests two basic representations of information corresponding to temporal patterns and frequencies (the inspiration comes from the "left brain talks, right brain sings" metaphor).

3. The explanation of Sheldrake for dominating/recessive genes in terms of morphic resonance implying that normal gene expression is a genetic habit based on majority decision of members of species in the past is very elegant but need not be correct of course!

If the antenna frequency of the corresponding genes (alleles) in the chromosome pair are same and corresponds to the antenna frequency of either parent, the gene corresponding to this frequency is expressed. Suppose that this frequency corresponds to the same dark photon energy so that the frequencies are inversely proportional to Planck constant so that higher Planck constant would correspond to a lower frequency. Could the lower frequency defined the common antenna frequency for chromosomes so that the parent with larger value of Planck constant would dominate? This option would explain the dominance differently and normal would correspond to the larger value of Planck constant. The mutations favoring the increase the value of Planck constant would be favored. NMP - understood in sufficiently strong sense- would favor the increase of Planck constant quite generally. One must of course be however very cautious in order to avoid systematic use of NMP to fill the holes in the theory.

4. What is the role of magnetic body and of topological quantum computer programs coded by braidings? Certainly this level should be very closely related to morphic fields. The function of introns is not well-understood and the obvious question is whether the flux tubes emerging from introns could be responsible for quantum computer like activities defining the real software [K5, K115]. Is the magnetic body itself genetically coded and does temporal self-organization patterns - behavior - correspond to this coding?

   It is known that the distribution of codons in intronic portion mimic distribution of letters in natural languages. Could the intronic part of the genome code for the magnetic body, in particular its braiding? What is the effect of external perturbations inducing flow of lipids at lipid layers of cell membrane to the braiding. Zipf law (see `http://tinyurl.com/7cbaj`) stating that the frequency of the word of natural language is proportional to its rank defined according to the ordering defined by its frequency of occurrence holds also for artificial words identified as sequences of subsequent intronic DNA nucleotides of fixed length. Does this mean that intronic DNA defines some kind of language.

5. A reasonable guess is that adaptation affects the genetic programs identified as topological quantum computer programs but not DNA and only rarely even genome (as in case of methylation). In mutation the hardware- genome- is affected and the question concerns the mechanism for the transformation of adaptation to mutation. Dark nuclei define representation of the genetic code and the following proposal is a suggestion for how this could happen.

Dark nucleons, genetic code, and its modifications

Dark nucleons represent genetic code in TGD Universe. What could be their role in the gene expression and in the evolution of genome? Cold dark nucleons define a kind of R&D laboratory allowing to test various kinds of DNA sequences.

1. The basic idea is that any polar molecular is covered by an "ice layer" consisting of ordered water. Assume that this layer determines the magnetic body of the molecule. External perturbation such as the feed of energy cuts the hydrogen bonds connecting the molecule to this layer and molecule can temporarily loose its magnetic body. Assume that this process generates sequences of dark nucleons (dark nuclei consisting of dark protons) which correspond to RNA, DNA, tRNA or amino-acid sequences. In this manner polar molecule would get name coded by the dark nuclei. If transcription of this sequence to DNA or RNA exists, it is possible to assign to this sequence DNA sequence serving as a gene coding for a protein which interacts resonantly with the polar polar molecule via the antenna frequencies defined by the cyclotron frequencies of its magnetic body. This would allow to generate a gene coding for gene attaching to the invader molecule.

2. At least in the case of immune system one might think that system is able to perform genetic engineering as a response to molecules invading to the system and I have proposed a mechanism for this. The transcription of dark genes represented as dark nuclei to DNA or RNA could provide a completely new mechanism of modifying the genome of egg and sperm cells since dark nuclei could penetrate cell membrane without difficulty.

3. Could the mechanism assigning to polar molecule a protein attaching to it allow the transformation of adaptation to mutation? If some protein defines a bottleneck step in adaptation, one could imagine that the transcription of the dark nucleon assigned with this protein to a piece of RNA reverse transcribed to DNA could transform the adaptation to mutation. More generally, if some proteins appear as basic steps in adaptive production of the change of phenotype then this process applied to them could produce the desired mutation of DNA.

4. Also collective genetic modifications can be imagined if there are genes inducing standard genetic modifications. Hardware would modify itself. Species could modify itself by using remote or collective expression of this kind of genes. Recall that retroviruses consist of RNA and reverse transcriptase catalyzing the reverse transcription of RNA to DNA in turn yielding the copies of retrovirus via transcription to mRNA and RNA. If RNA era continues in cell nucleus one can ask whether genome is continuously modified by the attachments of reversely transcribed DNAs from pieces of RNA. Reverse transcription has a high error rate.

To sum up, TGD approach would allow physical interpretation for morphic fields making possible remote gene expression and perhaps even remote genetic engineering. The past of species would affect the recent species. Both spatial and temporal non-locality would be key elements of life making possible memory and planned action.

10.7 Some Considerations Relating To The Dynamics Of Quasicrystals

The dynamics of quasicrystals (see `http://tinyurl.com/67kz3q`) [L8] looks to me very interesting because it shares several features of the dynamics of Kähler action defining the basic variational principle of classical TGD and defining the dynamics of space-time surfaces. In the following I will compare the basic features of the dynamics of quasicrystals to the dynamics of preferred extremals of Kähler action (see `http://tinyurl.com/ydyo6mab`) [K16].

Magnetic body carrying dark matter is the fundamental intentional agent in TGD inspired quantum biology and the cautious proposal is that magnetic flux sheets could define the grid of 3-planes (or more general 3-surfaces) defining quasi-periodic background fields favoring 4-D quasicrystals or more general structures in TGD Universe. Also 3-D quasicrystal like structures defined by grids of planes can be considered and 4-D quasicrystal structure could represent their time evolution.

Quite recently it has been reported (see `http://tinyurl.com/876lmaw`) that grids consisting of 2-D curved orthogonal surfaces characterize the architecture of neural wiring so that this hypothesis might make sense. This structure would be analogous to 2-D quasicrystal and its time evolution to 3-D quasicrystal.

10.7.1 The Non-Determinism For The Dynamics Of Quasicrystals Contra Non-Determinism Of Kähler Action

The dynamics of quasicrystals is non-deterministic in the sense that one cannot construct a unique quasicrystal by starting from a finite portion or even D-1-dimensional section of D-dimension quasicrystal thickened to a slice. Four-dimensional quasicrystals would therefore define a non-deterministic dynamics. This dynamics could serve as a geometric correlate for a full non-deterministic quantum dynamics involving also state function reductions. This requires that quantum classical correspondence is generalized so that also non-deterministic aspects of quantum dynamics are required to have geometric space-time correlates. The global empires of the 4-D quasicrystal could be interpreted as self-organization patterns whereas global empires would represent long range correlations.

This is very much analogous to 4-D spin glass degeneracy in TGD framework.

1. In TGD framework the preferred extremals of so called Kähler action define the dynamics of space-time surfaces. Kähler action [K46] is Maxwell action for the gauge field induced from the Kähler form of CP_2. Symplectic transformations of CP_2 act as abelian gauge

transformations and therefore leave the induced Kähler form invariant. They do not however leave the induced metric invariant so that the action changes by a contribution assignable to classical gravitation. For vacuum extremals however the symplectic transformations act as symmetries.

2. This implies huge vacuum degeneracy. Every space-time surface for which CP_2 projection is Lagrangian manifold and thus having at most 2-D CP_2 projection has vanishing induced Kähler form and is therefore vacuum extremal: there is infinite number of 6-D vacuum sectors labelled by Lagrangian sub-manifolds of CP_2 transformed to each other by symplectic transformations. These vacuum extremals behave non-deterministically which means an analogy with quasicrystal dynamics and suggests that quasicrystals might define a simplified model for quantal self-organization.

3. Small deformations of these define non-vacuum extremals and It is very conceivable that part of the vacuum degeneracy remains and is manifested as multi-furcations. The number n of branches for a multi-furcation has interpretation in terms of effective Planck constant $\hbar_{eff} = n\hbar$ to which dark matter is assigned in TGD framework. This degeneracy is very much analogous to a 4-dimensional spin glass degeneracy meaning that space-time decomposes to deterministically behaving regions just like spin glass decomposes to magnetized regions with varying direction of magnetization.

4. The interpretation for the situation in TGD framework is in terms of quantum classical correspondence: not only quantum states correspond to space-time geometries as analogs of Bohr orbits but also quantum jump sequences - which according to TGD inspired theory of consciousness define the contents of consciousness - have non-deterministic space-time geometries as geometric correlates. Space-time geometry and topology are like written text providing information about contents of consciousness.

5. Also p-adic topology as effective topology of space-time surfaces and natural topology for the landscape of extrema of Kähler function of WCW defining its Kähler geometry emerges naturally from this degeneracy. In physics obeying effective p-adic topology the counterpart would be short range chaos with long range correlations in the sense that one would have periodicity in the sense that physical states at time time at and $t + kp^n$, $k = 0, 1, ...p - 1$, $n \geq\geq 1$, would be very near to each other. The interpretation in terms of intentional action would be natural.

   One could also imagine of defining the analogs of empires as connected deterministic regions of space-time surface and the analogs of empires would be unions of disconnected components perhaps understandable in terms of p-adicity. Self-organization patterns would naturally correspond to these regions. Many-sheeted space-time would imply fractal hierarchy of self-organization patterns within self-organization patterns.

10.7.2 The Dynamics Of Quasicrystals As A Model For Fundamental Dynamics Or High Level Symbolic Dynamics?

Stephen Wolfram (see `http://tinyurl.com/6hztdo`) has suggested that cellular automatons could define the fundamental dynamics. It is not difficult to invent grave objections against this view. One of the objections is that this kind of dynamics is based on simple and rather ad hoc rules and applies to a society rather than to elementary particles. It is difficult to circumvent this counter argument.

One can however ask in what scale the symbolic dynamics does emerge? For few years ago my answer would have been "in biological length scales" (genetic code as symbolic dynamics). TGD Universe is however fractal, and this forces to ask whether this symbolic dynamics emerges already above CP_2 scale in some rudimentary form. In any case, even in this case the dynamics of self-organization would not be identifiable as the fundamental dynamics but as analogous to the rules of behavior in society.

The dynamics of quasicrystals brings indeed strongly in mind the dynamics of self-organization patterns prevailing at relatively high level of dynamical hierarchy. Symbolic dynamics prevailing at the level of biomolecules (genetic code) and at higher levels could be in question. This dynamics is dynamics for a society of conscious entities, which can decide whether to follow the rules or not. Rules as such do not matter too much: what is important that they make possible to predict the behavior of individuals and therefore make possible co-operation and formation of coherent and synchronous large scale structures making possible collective consciousness. In human society moral rules, laws, traffic rules, grammatical rules of language, etc... are examples about symbolic dynamics having very little to do with the laws of physics at fundamental level.

A natural question is whether the rules for building quasicrystals could provide a simplified model for this "social" dynamics - or perhaps even semi-realistic description - at the molecular level? Either quasicrystals or their building bricks - the arguments to be discussed later suggest that finite-sized quasicrystals - could be seen as a kind of society. The refusal to obey the rules guaranteeing the formation of larger quasicrystals would stop the quasicrystal growth and isolate the individual quasicrystal from the society. It could also lead to metabolic starvation: metabolic energy feed is indeed crucial element in living systems.

Quasicrystals could be seen as idealized structures having maximal complexity and therefore ability to represent information. Critical systems - also quantum critical ones - have a universal dynamics so that there is a large number of models making the same predictions for a given system. In practice this can be used to find the simplest possible model to simplify the mathematical description (say by finding the simplest conformal field theory to describe a 2-D critical system). From this point of view quasicrystals could be seen as an especially simple model possibly able to catch the universal properties of a real world system.

Does this self-organization dynamics then emerge only at and above bio-molecular scales or in all scales?

1. In TGD framework the classical dynamics at the fundamental level would be the geometrodynamics of space-time surfaces (see `http://tinyurl.com/ybp86sho`) [K109]. Quantum Dynamics would be dictated by Dirac equation for WCW ("world of classical worlds") spinor fields and reduce to the modified Dirac equation (see `http://tinyurl.com/y8ha6fuy`) for second quantized induced spinor fields at space-time surfaces.

   The fractality of the TGD Universe suggests that self-organization occurs in all length scales above CP_2 scale, which is about 10^4 times Planck scale. If so, structures analogous to finite pieces quasicrystals could appear in all scales down to CP_2 scale.

2. I have proposed a method for constructing preferred extremals of Kähler action [K119] and this recipe leads to an iteration procedure. Quite generally, iteration is known to lead to fractals as fixed sets of iteration. Therefore space-time surfaces could be seen as space-time correlates of self-organization patterns and fractals.

3. Fractality would mean that even inanimate matter should share some aspects assigned to living matter and that also systems like species and biosphere could behave like living organisms in some respects. Sheldrake is famous for his notion of memory at the level of entire species. He has also proposed that even inanimate systems could have "habits". For instance, minerals would have adopted the habit to crystallize to a particular crystal form. In this framework living matter would differ from mineral kingdom in that its habits would be much more flexible. I have discussed the implementation of Sheldrake's ideas in TGD framework (see `http://tinyurl.com/y79kxbua`) [L6].

10.7.3 Could Ordered Water Layers Around Biomolecules Be Modelled As Quasicrystal Like Structure?

Water forms multilayered quasi-lattices (to be distinguished from quasicrystals!). These quasi-lattices around molecules are like ice coverings. These quasilattices have water molecule as a basic tetrahedral building blocks giving rise to icosahedral blocks (as suggested in discussions): the 4 electron pairs of water molecule are indeed located at the vertices of tetrahedron and for lattice like structures a regular tetrahedron is in question. Perhaps these quasi-lattices could be modelled as deformed quasicrystals.

This molecular ice would form a quasicrystal, which could somehow store information about environment via its structural degeneracy. If the information is conscious, it should be stored in the negentropic entanglement between the states of finite-sized quasi-lattices surrounding two separate molecules, and would have magnetic flux sheets connecting them as a space-time correlate. For 3-D quasicrystal like structure the lattice points would be in the intersections of 3 2-planes (or thin locally planar flux sheets) and define points of a lattice at which the analogs of coordinate planes meet.

Making these structures dynamical one would obtain 4-D quasicrystal like structures. In this case the intersections of 2 3-planes (or thin locally planar 3-D flux sheets) would give rise to 1-dimensional word lines of 3-D quasicrystal points whereas the intersections of 3 3-planes would correspond to points of 4-D lattice. What special could happens at these dynamically special points of space-time?

Zero energy ontology and TGD inspired theory of consciousness allows to consider a possible answer: the points of 4-D lattice correspond to CDs (causal diamonds) serving as space-time correlates for sub-selves identifiable as mental images. Quite generally quasi-periodically appearing mental images might be assigned to the points of quasi-lattice like structure.

Note that also cubic crystals can be constructed using grid consisting now of 3 orthogonal planes and the distances between grid planes serve as geometrical parameters which magnetic body could vary. The constant deformation of the magnetic body would now however force rather large deformations of crystal structure probably impossible energetically. One can however ask whether phonons could be induced by the local deformations of the flux sheets of the grid inducing small oscillations of the lattice points. If the magnetic body indeed serves as the intentional agent using biological body, this connection might allow to understand the very special role of acoustic oscillations in hearing, speech, internal speech, and thought. For instance, could the reaction of magnetic flux sheets to sound give rise to hearing? And could the reaction of the quasilattice units to the oscillations of the flux sheets give rise to internal speech or induce even speech in sound organs? It has been argued that the structure of the intronic portion of DNA resembles that of language and this has led to proposal that acoustic waves propagating along DNA could code for language. If DNA is indeed accompanied by flux tubes and flux sheets, this idea would look rather natural in the recent context.

One of the basic findings of biology is that protein molecules are most of the time in a resting state in a folded configuration with globular form and surrounded by ordered water defining kind of ice covering. This state could represent conscious information realized as a negentropic entanglement between different molecules: kind of a molecular meditative state would be in question. In the presence of energy feed inducing "molecular summer" the molecular ice would melt, globular proteins would open and self-organize to form molecular aggregates as a reaction to the energy feed. After the energy feed stops, molecules would fold back to the globular form but the memory from the "molecular summer" would be stored to the negentropic entanglement between molecules.

The Indra's net formed by the magnetic flux tubes and sheets has become a standard part of TGD based view about living matter. The model for "DNA as quantum computer" (see `http://tinyurl.com/ybyscdpt`) [K5] involves flux sheets traversing through DNA strand and flux tubes connecting nucleotides to lipids of the cell membrane as well as flux sheets with the shape of cell membrane. This suggests that one actually has also in the case of DNA-cell membrane system three orthogonal grids of flux sheets at some scale and flux tubes condensed at the sheets of grids. These structure would organized the living matter to a well-organized geometric structure.

One of the first really crazy ideas (see `http://tinyurl.com/yaf2pww3`) related to the magnetic was the proposal that the magnetic bodies associated with living organisms could have shape reflecting the shape of the organism and its parts - even in the length scale of Earth [K54]. If one takes the flux sheets grids seriously, and replaces planes with closed surfaces obtained by scaling outer surfaces for parts of the organism, something like this is indeed expected.

10.7.4 What Could Be The Variational Principle Behind Self-Organization?

Quasicrystals, say Penrose tilings (see `http://tinyurl.com/yc75bvd8`), have a huge ground state degeneracy: given region of quasicrystal can be completed to infinite number of quasicrystals. For crystals the situation is different: local empire is the entire infinite crystal. Quasicrystals are clearly analogous to spin glass systems also possessing also large ground state degeneracy.

TGD Universe is a 4-D spin glass, and this degeneracy would imply non-determinism analogous to the non-determinism of quasi-crystal dynamics in 4-D 4-D Minkowski space) with local empires interpreted as self-organization patterns and global empires reflecting the long range correlations due to intentional action and obedience for social rules. In human society the ability to predict what person probably does next year in given day only by knowing his profession, would represent example about this kind of long range correlation caused basically by social forces.

Why Negentropy Maximization Principle should favor quasicrystals?

In TGD inspired theory of consciousness Negentropy Maximization Principle (NMP) (see `http://tinyurl.com/yd3mly5m`) [K59] is the basic variational principle. NMP states that the information contents of conscious experience is maximal. Therefore entanglement negentropy is expected to be the fundamental quantity.

1. Since conscious entities forming larger coherent structures (societies) are in question, it seems that one should characterize the quasi-lattice by a negentropy, which should be maximized (purely mathematically negentropy is very similar to entropy which is maximized for a closed system). This negentropy would *not* correspond to the negative of the ordinary thermodynamical entropy, which characterizes ensemble of particles rather than single coherent unit.

2. In TGD Universe this negentropy would naturally be the number theoretic negentropy characterizing negentropic entanglement (see **Fig.** `http://tgdtheory.fi/appfigures/cat.jpg` or **Fig. ??** in the appendix of this book) identified as a measure for conscious information. This information measure is assigned with the magnetic flux tubes connecting biomolecules and other units of living organism and even living organisms to larger coherent structures. In the case of quasicrystals flux tubes or flux sheets give rise to the long range constraints binding the units of quasi-crystal to each other.

3. The maximization of negentropy characterizing information content of conscious experience should be equivalent with the maximization of complexity as the number of almost degenerate ground states of quasicrystal. It is intuitively clear why quasicrystals would be favored over crystals. But how quasicrystals could maximize entanglement negentropy? Why the entanglement negentropy would be large for quasicrystals? Why the large number of quasicrystals configurations would favor large entanglement negentropy.

   If the entanglement is between two different quasicrystals, it means formation of quantum superposition of pairs of quasicrystal configurations and the higher the quasicrystal degeneracy, the larger the maximal entanglement negentropy. This conforms with the fact that quasicrystals are necessary of finite size. Most naturally the negentropic entanglement would be between the degenerate ground states of two finite-sized quasicrystals.

4. If degrees of freedom associated with the space-time geometry are entangled, the quantum dynamics at the level of "world of classical worlds" would be involved and by definition would not be describable by QFT in a fixed background space-time. One could speak about genuine quantum gravity: The Orch-OR proposal of Penrose and Hameroff is also a conjecture of similar character. One can also consider entanglement between states of some particle and quasicrystal but the negentropy content would be now much smaller due to the small number of particle states.

Maximal capacity to represent information with minimal metabolic energy costs as a basic variational principle?

The interpretation as a symbolic dynamics assignable to conscious entities would suggest that the maximization of the capacity to represent information (perhaps with minimal metabolic costs) could be the variational principle behind this dynamics. The number of different quasicrystals formed using the given rules should be maximal. This would give rise to very large number of states with nearly same energy allowing to represent the states of the external world (primitive sensory system). The larger the size of quasicrystal, the larger the number of degenerate configurations. Here of course physical constraints would pose an upper limit of the size.

But can one really assume rigid rules of construction giving rise to only quasicrystals? If the basic dynamical units are conscious entities they refuse to obey strict rules although they can decide to do so under "social pressures" (absence of metabolic energy feed can transform a sinner a saint!). Should these rules be an outcome of the variational principle alone? Or are they forced by some minimization principle - say minimization of metabolic energy feed - in presence of quasi-periodic background field configuration regarded as an external field favoring quasicrystals?

It seems that all configurations of the basic units must be accepted a priori: in principle even random spatial configurations of the basic units. For random configurations complexity would be maximal but co-operation minimal, long range correlations would be absent, and the ability to represent information would be minimal. For crystals long range correlations and co-operation would be maximal but crystal would have minimal capacity to represent and mimic. The natural manner to achieve long range correlations is to assume slowly varying quasi-periodic fields configurations representing the "social forces". In TGD framework these fields would naturally correspond to magnetic flux quanta serving as basic building bricks of magnetic bodies controlling biological body.

Note that by previous argument, the capacity to store conscious information is equivalent with ability to generate negentropic entanglement.

A possible realization for 4-D dynamics favoring quasicrystal like structures

Can one imagine a physical realization of 4-D quasicrystal dynamics in TGD framework? The basic problem is to understand how the rules for the formation of quasicrystals are forced. Certainly the hyper-plane grids associated with the basic polytope defining the quasicrystal force the long range correlations. But how to realize these grids physically?

1. In TGD Universe magnetic body acts as an intentional agent using biological body as a motor organ and sensory receptor. This suggests that the plane grids parallel to the faces of - say - icosahedron in the case of 3-D quasicrystal could in TGD Universe be realized as thin (and thus effectively 2-D) magnetic flux sheets forming the magnetic body around which the ordinary matter would self-organize to form a quasicrystal as a configuration sustainable by using minimum metabolic energy feed. These grids would be part of the magnetic body responsible for the "social forces".

   Rather remarkably, quite recent findings strongly suggest that brain involves an orthogonal grid of curved planes.(see `http://tinyurl.com/876lmaw`) Maybe this grid correspond to a quasi-lattice associated with a cubic basic unit serving as a basic information processing unit. Exact cubic crystal does not guarantee the needed ground state degeneracy and the deviation from it could be crucial in guaranteeing large degeneracy of the basic structures.

2. Maybe the basic variational principle could be minimization of the metabolic energy feed in presence of fixed grid structure formed by flux sheets representing the slow dynamics to which the molecular dynamics would rapidly adapt. The intersections of the grid hyper-planes are good candidates for the equilibrium points and going outside them would require metabolic energy. The minimum of the magnetic energy $\mu \cdot B$ of magnetic dipole is reduced in the intersections of flux sheets if the effects of the magnetic fields sum up at the intersection. For the crossing of n orthogonal sheets there is an enhancement by $\sqrt{n}$ factor. The motor activities of the magnetic body itself would deform the quasicrystals: the flux sheets could be deformed and the distances between the flux sheets could also vary. This would lead to new quasicrystal configurations with high negentropic content.

   From the point of view of individual quasicrystal regarded as conscious entity fight for survival would be fighting for metabolic resources and fusion with a bigger quasicrystal could be one manner to guarantee the availability of metabolic energy.

3. Phason dynamics (see `http://tinyurl.com/ycb86kzc`) seems to allow both short range description in terms of permutations of basic units and long range hydrodynamical description. Two dynamics seem to be present: slow *resp.* fast dynamics in short *resp.* long scales. Maybe these paradoxical properties of phasons could be understood in this framework if the microscopic fast dynamics forced by the slow long length scale dynamics of flux sheets.

4. Also other than quasicrystal configurations would be possible but would require higher metabolic energy feed to preserve entanglement negentropy (amount of conscious information). In 4-D case one would have similar grids of thin and effectively 3-D magnetic flux

sheets associated with the 3-D faces (maybe icosahedrons) of 4-D building brick of quasicrystals. Magnetic flux sheets would carry dark matter and give rise to negentropic entanglement between the units of the quasicrystal.

5. The negentropic entanglement between two different quasi-crystal like structures means quantum superposition of different space-time surfaces since the grids formed by the flux sheets would have different geometric parameters such as the distance between the flux sheets of the grid. Hence genuine quantum gravitational effects would be in question having no description in QFT framework and requiring description at the level of WCW .

Summary

The essential element of picture would be spin glass degeneracy giving a large number of ground states making possible highly negentropic entanglement between separate spin glasses. Quasicrystals are not the only manner to satisfy this condition and 4-D quasi-lattices for which grid could contain also more general 3-surfaces than hyperplanes, can be considered. Grids of thin 3-surfaces would represent the rules forcing the quasi-lattice like configurations through localization to the word lines defined by intersections of two 3-surfaces. TGD inspired quantum model for biology suggests concrete models for the grids of flux sheets involving also flux tubes topologically condensed on them as a way to generate negentropic entanglement. Also fractal structures consisting of flux quanta inside flux quanta are highly suggestive.

The basic variational principle of quasicrystal dynamics (and its generalization to quasi-lattices) could be minimization of metabolic energy feed in presence of fixed configuration of the magnetic body obeying a relatively slow dynamics. The time scale of EEG is in the range.01-.1 seconds gives a first guess for the time scale of the dynamics of the magnetic body in scale of Earth. This time scale is to be compared to the time scale of 10^{-10} seconds of conformational dynamics bio-molecules. Quasi-crystallization - or more generally, formation quasi-lattices - would be due to the existence of grids of thin 3-sheets parallel to the basic units of the 3-faces of 4-D basic unit of quasicrystal.

To show that this picture makes or does not make sense, one should be able to estimate reliably the metabolic energy feed needed to preserve a given negentropic entanglement entropy for a given configuration of the basic units (say clusters of water molecules) and to show that it is minimized for quasicrystal configurations in presence of the grid structure formed by flux sheets. This is probably relatively easy since the first guess for the equilibrium configurations corresponds to the highly symmetric crossing lines of for two 3-planes. One might also try to demonstrate the presence of negentropic entanglement between molecules, which are in resting state. This would be a direct demonstration for the notion of WCW and for non-trivial quantum gravity effects in living matter.

10.7.5 Could Quasi-Lattices And Quasi-Crystals Emerge From The Notion Of P-Adic Manifold?

This section is inspired by the considerations of the new chapter "What p-adic icosahedron could mean? And what about p-adic manifold?" [K120]. The original purpose was to understand what the notion of p-adic icosahedron could mean but soon it turned out that the key challenge is to understand what p-adic manifold means. Also in TGD framework this is one of the basic challenges posed by the condition of number theoretical universality and the idea about algebraic continuation of physics between different number fields.

The basic problem is that p-adic topology is totally disconnected meaning that p-adic balls are either disjoint or nested so that the usual construction of manifold structure fails. The basic criticism against the notion of p-adic icosahedron, and more generally, the notion of p-adic manifold, is the technical complexity of the existing constructions by mathematicians.

TGD however suggests much simpler construction. The construction relies on a simple modification of the notion of manifold inspired by the interpretation of p-adic preferred extremals defining counterparts of real preferred extremals as cognitive representations of the latter. This requires a mapping from p-adic preferred extremals to real ones and vice versa. In manifold theory chart maps are the analogs of these maps and the only difference is that they are between different number fields.

What I have christened as canonical identification $I_{k,l}^Q$ mapping rationals $p^{rk}m/n$ with $|m|_p > p^{-k}$, $|n|_p > p^{-k}$, as $I_{k,l}^Q(p^{rk}(m/n)) = p^{-rk}I_{k,l}(m)/I_{k,l}(n)$, where $I_{k,l}(m = \sum m_n p^{nk}) = \sum_{n<l} m_n p^{-nk}$ defines canonical identification for p-adic numbers m, n satisfying the above conditions in their pinary expansion with two cutoffs k and l. $I_{k,l}^Q$ is ill defined for irrational p-adic numbers since for them the representation as rational is not unique. A generalization to algebraic extensions is straightforward.

$I_{k,l}^Q$ is a compromise between the direct identification along common rationals favored by algebra and symmetries but being totally discontinuous without the cutoff $n < l$. This cutoff breaks symmetries slightly but guarantees continuity in finite measurement resolution defined by the pinary cutoff l. Symmetry breaking can be made arbitrarily small and has interpretation in terms of finite measurement resolution. Due to the pinary cutoff the chart map applied to various p-adic coordinates takes discrete set of rationals to discrete set of rationals and preferred extremal property can be used to make a completion to a real space-time surface. Uniqueness is achieved only in finite measurement resolution and is indeed just what is needed. Also general coordinate invariance is broken in finite measurement resolution. In TGD framework it is however possible to find preferred coordinates in order to minimize this symmetry breaking.

TGD based view about p-adic manifolds

The construction of p-adic manifold topology somehow overcoming the difficulty posed by the fact that p-adic balls are either disjoint or nested is necessary. It should also allow a close relationship between p-adic and real preferred extremals. It will be found that TGD leads naturally to a proposal of p-adic manifold topology [K120] based on canonical identification used to map the predictions of p-adic mass calculations to real numbers. This map would define coordinate charts for p-adic space-time surfaces - not as p-adic chart leafs as in the standard approach - but as real chart leafs. The real topology induced from real map leafs to the p-adic realm would be path-connected as required.

In TGD framework one must also require finite measurement resolution meaning that the canonical identification is characterized by pinary cutoff takes a discrete subset of rational points of p-adic preferred extremal to its real counterpart: for a subset of this subset rationals are mapped to themselves. One can complete this point set to a real preferred extremal in finite measurement resolution. This construction allows also to define p-adic integrals and differential forms in terms of their real counterparts by algebraic continuation. Therefore geometric notions like distance and volume make sense and there is a very close correspondence between real space-time geometries and their p-adic counterpart in the situations when they exist.

Can one consider a p-adic generalization of Penrose tiling and quasicrystals?

The mathematically rigorous generalization of Penrose Tilings and quasicrystals to p-adic context might be possible but is bound to be rather technical. The p-adic icosahedron as it is defined in the article does not seem very promising notion. The point is that it is defined in terms of fixed point set for subgroups of icosahedral group acting on Riemann sphere: the action in Euclidian 3-space is now more natural and certainly makes sense and actually simplifies the situation since Q_p^3 sd analog of E^3 is simplest possible 3-D p-adic manifold. It does not however allow Bruhat-Tits tree since the points of Q_p^n are not in 1-1 correspondence with the lattices of Q_p^n. The possibility to construct Bruhat-Tits tree is a special feature of projective spaces.

TGD based view about p-adic E^3 and S^2 as its sub-manifold allows to define also the counterpart of Penrose tiling and QCs in an elegant manner with a close relationship between real and p-adic variants of QC.

1. If one considers lattices in n-dimensional p-adic space Q_p^n replacing E^n, a more natural definition would be in terms of this space than in terms of sphere. For the counterpart of E^3 one can define the action of the subgroup A_5 of rotation group $SO(3)$ by introducing an algebraic extension of the p-adic numbers containing $cos(2\pi/5)$, $sin(2\pi/5)$ and $cos(2\pi/3)$, $sin(2\pi/3)$ and their products. What is interesting is that algebraic extension is forced automatically in

p-adic context! In cut and project (see http://tinyurl.com/ybdbvjoa) method [A11] the QC structure requires also this since the imbedded space has an algebraic dimension over integers equal to the dimension of the embedding space over reals.

Could it be that p-adic variants of QCs might provide number theoretic insights about QCs? Subspace would define algebraic extension of p-adic numbers and this extension would be such that it allows the representation of the isometry group of the Platonic solid possibly assignable to the QC.

2. One can also now define the icosahedron or any Platonic solid in terms of fixed points also now. Only discrete subgroups of the rotation group can be represented p-adically since algebraic extension is required. This brings in mind the notion of finite measurement resolution leading to a discretization of p-adically representable rotations and more general symmetries. For instance, without algebraic extension only rotations for which the rotation matrices are rational numbers are representable. It seems that finite subgroups of this kind are generated by rotations with rotation angle $\pi/2$ around various coordinate axes. Pythagorean triangles correspond to rationals values of cosine and sine and rotations for which rotation angle corresponds to Pythagorean angle define rational rotation matrices: these groups are discrete but contain infinite number of elements.

   Altogether this suggests a hierarchy of p-adic extensions leading to higher algebraic dimensions and larger discrete symmetries. This conforms with the general number theoretic vision about TGD.

3. Lattices in Q_p^n with integer coefficients make also sense and are characterized by n linearly independent (over p-adic integers) basic vectors $(a_1, ..., a_n)$. Most points of lattice would correspond to values of p-adic integers n_i in $\sum_i n_i a_i$ infinite as real numbers.

   Consider first a non-realistic option in which p-adic integers are mapped to p-adic integers as such. Note also that most of p-adic lattice points would map to real infinity. This kind of correspondence makes sense also for rationals but would give a totally discontinuous correspondence between reals and p-adics.

   p-Adic manifold topology defined in terms of the canonical identification I_{kl} allows to interpret the p-adic lattice as a cognitive representation of the real one. The presence of pinary cutoffs k and l having interpretation in terms of finite cognitive resolution has two implications. Integers $n_i < p^k$ are mapped to themselves so that this portion of lattice is mapped to itself faithfully. The integers $k \leq n < l$ are not mapped to integers and the length of the image is bounded below. The real image of the p-adic lattice under I_{kl} is necessary compressed to a finite volume of E^3. This kind of compression and cutoff is natural for cognitive representations for which numerics with finite cutoff provides one particular analogy.

4. Could the notion of p-adic QC and Penrose tiling make sense if one considers p-adic counterparts of Euclidian space and a n-D cubic lattice with integer valued coefficients and spanned by unit vectors? Could the cut and project method (see http://tinyurl.com/ybdbvjoa) [A11] generalize?

   This is not clear since projection would lead from a lattice in Q_p^n to a QC in lower-dimensional space which is associated with algebraic extension of Q_p but having algebraic dimension equal to n. If this space is K^m, K an algebraic extension of Q_p, one has $n = dim(K) \times m$. For prime values of n this would mean that $m = 1$ and one has n-D algebraic extension.

   Projection should be generalized to a map mapping points of n-D space to m-dimensional subspace K^m associated with algebraic extension of Q_p. Maybe it is better to formally extend Q_p^n to K^n and restrict the lattice to integer lattice in $Q_p^n \subset K^n$. In this manner the projection becomes well-defined as map from $Q_p^n \subset K^n$ to a subspace K^m of K^n. The basic condition could be that the points of the subspace K^m in K^n with algebraic dimension $n \times dim(K)$ define and m-dimensional subspace over K and n-dimensional subspace of Z_p.

   The "irrational angles" associated with the lower-dimensional subspace defining quasilattice defining algebraic extension of Q_p should be such that it allows the representation of the isometry group of the p-adic Platonic solid possibly assignable to the QC in question.

Cut and project construction of quasicrystals from TGD point of view

Cut and projec (see `http://tinyurl.com/ybdbvjoa`) [A11] method is used to construct quasicrystals (QCs) in sub-spaces of a higher-dimensional linear space containing an ordinary space filling lattice, say cubic lattice. For instance, 2-D Penrose tiling is obtained as a projection of part of 5-D cubic lattice - known as Voronyi cell - around 2-D sub-space imbedded in five-dimensional space. The orientation of the 2-D sub-space must be chosen properly to get Penrose tiling. The nice feature of the construction is that it gives the entire 2-D QC. Using local matching rules the construction typically stops.

1. Sub-manifold gravity and generalization of cut and project method

The representation of space-time surfaces as sub-manifolds of 8-D $H = M^4 \times CP_2$ can be seen as a generalization of cut and project method.

1. The space-time surface is not anymore a linear 4-D sub-space as it would be in cut and project method but becomes curved and can have arbitrary topology. The embedding space ceases to be linear $M^8 = M^4 \times E^4$ since E^4 is compactified to CP_2. Space-time surface is not a lattice but continuum.

2. The induction procedure geometrizing metric and gauge fields is nothing but projection for H metric and spinor connection at the continuum limit. Killing vectors for CP_2 isometries can be identified as classical gluon fields (see **Fig. 10.4**). The projections of the gamma matrices of H define induced gamma matrices at space-time surface. The spinors of H contain additional components allowing interpretation in terms of electroweak spin and hyper-charge.

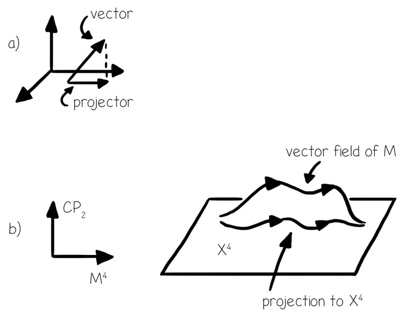

Figure 10.4: Induction of spinor connection and metric as projection to the space-time surface

2. Finite measurement resolution and construction of p-adic counterparts of preferred extremals forces "cut and project" via discretization

In finite measurement resolution realized as discretization by finite pinary cutoff one can expect to obtain the analog of cut and project since 8-D embedding space is replaced with a lattice structure.

1. The p-adic/real manifold structure for space-time is induced from that for H so that the construction of p-adic manifold reduces to that for H.

2. The definition of the manifold structure for H in number theoretically universal manner requires for H discretization in terms of rational points in some finite region of M^4. Pinary cutoffs- two of them - imply that the manifold structures are parametrized by these cutoffs charactering measurement resolution. Second cutoff means that the lattice structure is piece of an infinite lattice. First cutoff means that only part of this piece is a direct imagine of real/p-adic lattice on p-adic/real side obtained by identifying common rationals (now

integers) of real and p-adic number fields. The mapping of this kind lattice from real/p-adic side to p-adic/real side defines the discrete coordinate chart and the completion of this discrete structure to a preferred extremal gives a smooth space-time surface also in p-adic side if it is known on real side (and vice versa).

3. Cubic lattice structures with integer points are of course the simplest ones for the purposes of discretization and the most natural choice for M^4. For CP_2 the lattice is completely analogous to the finite lattices at sphere defined by orbits of discrete subgroups of rotation group and the analogs of Platonic solids emerge. Probably some mathematician has listed the Platonic solids in CP_2.

4. The important point is that this lattice like structure is defined at the level of the 8-D embedding space rather than in space-time and the lattice structure at space-time level contains those points of the 8-D lattice like structure, which belong to the space-time surface. Finite measurement resolution suggests that all points of lattice, whose distance from space-time surface is below the measurement resolution for distance are projected to the space-time surface. Since space-time surface is curved, the lattice like structure at space-time level obtained by projection is more general than QC.

The lattice like structure results as a manifestation of finite measurement resolution both at real and p-adic sides and can be formally interpreted in terms of a generalization of cut and project but for a curved space-time surface rather than 4-D linear space, and for H rather than 8-D Minkowski space. It is of course far from clear whether one can obtain anything looking like say 3-D or 4-D version of Penrose tiling.

1. The size scale of CP_2 is so small (10^4 Planck lengths) that space-time surfaces with 4-D M^4 projection look like M^4 in an excellent first approximation and using M^4 coordinates the projected lattice looks like cubic lattice in M^4 except that the distances between points are not quite the M^4 distances but scaled by an amount determined by the difference between induced metric and M^4 metric. The effect is however very small if one believes on the general relativistic intuition.

   In TGD framework one however can have so called warped embeddings of M^4 for which the component of the induced metric in some direction is scaled but curvature tensor and thus gravitational field vanishes. In time direction this scaling would imply anomalous time dilation in absence of gravitational fields. This would however cause only a the compression or expansion of M^4 lattice in some direction.

2. For Euclidian regions of space-time surface having interpretation as lines of generalized Feynman diagrams M^4 projection is 3-dimensional and at elementary particle level the scale associated with M^4 degrees of freedom is roughly the same as CP_2 scale. If CP_2 coordinates are used (very natural) one obtains deformation of a finite lattice-like structure in CP_2 analogous to a deformation of Platonic solid regarded as point set at sphere. Whether this lattice like structure could be seen as a subset of infinite lattice is not clear.

3. One can consider also string like objects $X^2 \times Y^2 \subset M^4 \times CP_2$ with 2-D M^4 projection and their deformations. In this case the projection of M^4 lattice to X^2 - having subset of two M^4 coordinates as coordinates - can differ considerably from a regular lattice since X^2 can be locally tilted with respect to M^4 lattice. This cannot however give rise to Penrose tiling requiring 5-D flat embedding space. This argument applies also to 2-D string world sheets carrying spinor modes. In the idealized situation that string world sheet is plane in M^4 one might obtain an analog of Penrose tiling but with 4-D embedding space.

The above quasi lattice like structures (QLs) are defined by a gravitational deformation of the cubic lattice of M^4. Is there any hope about the 4-D QLs in M^4 so that gravitation would give rise to the analogs of phason waves deforming them? Could cut and project method be generalized to give QL in M^4 as projection of 8-D cubic lattice in M^8?

3. $M^8 - H$ duality

Before considering an explicit proposal I try to describe what I call $M^8 - H$ duality ($H = M^4 \times CP_2$).

1. What I have christened $M^8 - H$ duality is a conjecture stating that TGD can be equivalently defined in M^8 or $M^4 \times CP_2$. This is the number theoretic counterpart of spontaneous compactification of string models but has nothing to do with dynamics: only two equivalent representations of dynamics would be in question.

2. Space-time surfaces (preferred extremals) in M^8 are postulated to be quaternionic sub-manifolds of M^8 possessing a fixed $M^2 \subset M^4 \subset M^8$ as sub-space of tangent space. "Quaternionic" means that the tangent space of M^4 is quaternionic and thus associative. Associativity conditions would thus determine classical dynamics. More generally, these subspaces $M^2 \subset M^8$ can form integrable distribution and they define tangent spaces of a 2-D sub-manifold of M^4. If this duality really holds true, space-time surfaces would define a lattice like structure projected from a cubic M^8 lattice. This of course does not guarantee anything: $M^8 - H$ duality itself suggests that these lattice like structures differ from regular M^4 crystals only by small gravitational effects.

3. The crucial point is that quaternionic sub-spaces are parametrized by CP_2. Quaternionic 4-surfaces of $M^8 = M^4 \times CP_2$ containing the fixed $M^2 \subset M^8$ can be mapped to those of $M^4 \times CP_2$ by defining M^4 coordinates as projections to preferred $M^4 \subset M^8$ and CP_2 coordinates as those specifying the tangent space of 4-surface at given point.

4. A second crucial point is that the preferred subspace $M^4 \subset M^8$ can be chosen in very many ways. This embedding is a complete analog of the embedding of lower-D subspace to higher-D one in cut and project method. M^4 can be identified as any 4-D subspace imbedded in M^4 and the group $SO(1,7)$ of 8-D Lorentz transformations defines different embeddings of M^4 to M^8. The moduli space of different embeddings of M^4 is the Grassmannian $SO(1,7)/SO(1,3) \times SO(4)$ and has dimension $D = 28 - 6 - 6 = 16$.

   When one fixes two coordinate axes as the real and one imaginary direction (physical interpretation is as an identification of rest system and spin quantization axes), one obtains $SO(1,7)/SO(2) \times SO(4)$ with higher dimension $D = 28 - 1 - 6 = 21$. When one requires also quaternionic structure one obtains the space $SO(1,7)/SU(1) \times SU(2)$ with dimension $D = 28 - 4 = 24$. Amusingly, this happens to be the number of physical degrees of freedom in bosonic string model.

4. How to obtain quasilattices and quasi-crystals in M^4?

Can one obtain quasi-lattice like structures (QLs) at space-time level in this framework? Consider first the space-time QLs possibly associated with the standard cubic lattice L^4_{st} of M^4 resulting as projections of the cubic lattice structure L^8_{st} of M^8.

1. Suppose that one fixes a cubic crystal lattice in M^8, call it L^8_{st}. Standard M^4 cubic lattice L^4_{st} is obtained as a projection to some M^4 sub-space of M^8 by simply putting 4 Euclidian coordinates for lattice points o constant. These sub-spaces are analogous to 2-D coordinate planes of E^3 in fixed Cartesian coordinates. There are $7!/3!4! = 35$ choices of this kind.

   One can consider also E_8 lattice (see `http://tinyurl.com/y9x7vevr`) is an interesting identification for the lattice of M^8 since E_8 is self-dual and defines the root lattice of the exceptional group E_8. E_8 is union of Z^8 and $(Z + 1/2)^8$ with the condition that the sum of all coordinates is an even integer. Therefore all lattice coordinates are either integers or half-integers. E_8 is a sub-lattice of 8-D cubic lattice with 8 generating vectors $e_i/2$, with e_i unit vector. Integral octonions are obtained from E_8 by scaling with factor 2. For this option one can imbed L^4_{st} as a sub-lattice to Z^8 or $(Z + 1/2)^8$.

2. Although $SO(1,3)$ leaves the imbedded 4-plane M^4 invariant, it transforms the 4-D crystal lattice non-trivially so that all 4-D Lorentz transforms are obtained and define different discretizations of M^4. These are however cubic lattices in the Lorentz transformed M^4 coordinates so that this brings nothing new. The QLs at space-time surface should be obtained as gravitational deformations of cubic lattice in M^4.

3. L^4_{st} indeed defines 4-D lattice at space-time surface apart from small gravitational effects in Minkowskian space-time regions. Elementary particles are identified in TGD a Euclidian

space-time regions - deformed CP_2 type vacuum extremals. Also black-hole interiors are replaced with Euclidian regions: black-hole is like a line of a generalized Feynman diagram, elementary particle in some sense in the size scale of the black-hole. More generally, all physical objects, even in everyday scales, could possess a space-time sheet with Euclidian metric signature characterizing their size (AdS^5/CFT correspondence could inspire this idea). At these Euclidian space-time sheets gravitational fields are strong since even the signature of the induced metric is changed at their light-like boundary. Could it be that in this kind of situation lattice like structures, even QCs, could be formed purely gravitationally? Probably not: an interpretation as lattice vibrations for these deformations would be more natural.

It seems that QLs are needed *already at the level of* M^4. $M^8 - H$ duality indeed provides a natural manner to obtain them.

1. The point is that the projections of L^8_{str} to sub-spaces M^4 defined as the $SO(1,7)$ Lorentz transforms of L^4_{st} define generalized QLs parametrized by 16-D moduli space $SO(1,7)/SO(1,3)\times SO(4)$. These QLs include also QCs. Presumably QC is a QL possessing a non-trivial point group just like Penrose tiling has the isometry group of dodecagon as point group and 3-D analog of Penrose tiling has the isometries of icosahedron as point group.

   This would allow to conclude that the discretization at the level of M^8 required by the definition of p-adic variants of preferred extremals as cognitive representations of their real counterparts would make possible 4-D QCs. M^8 formulation of TGD would explain naturally the QL lattices as discretizations forced by finite measurement resolution and cognitive resolution.

   A strong number theoretical constraint on these discretizations come from the condition that the 4-D lattice like structure corresponds to an algebraic extension of rationals. Even more, if this algebraic extension is 8-D (perhaps un-necessarily strong condition), there are extremely strong constraints on the 22-parameters of the embedding. Note that in p-adic context the algebraic extension dictates the maximal isometry group identified as subgroup of $SO(1,7)$ assignable to the embedding as the discussion of p-adic icosahedron demonstrates.

2. What about the physical interpretation of these QLs/QCs? As such QLs define only natural discretizations rather than physical lattices. It is of course quite possible to have also physical QLs/QCs such that the points - rather time like edge paths - of the discretization contain real particles. What about a "particle" localized to a point of 4-D lattice? In positive energy ontology there is no obvious answer to the question. In zero energy ontology the lattice point could correspond to a small causal diamond containing a zero energy state. In QFT context one would speak of quantum fluctuation. In p-adic context it would correspond to "though bubble" lasting for a finite time.

3. It is also possible to identify physical particles as edge paths of the 4-D QC, and one can consider time= constant snapshots as candidates for 3-D QCs. It is quite conceivable that the non-trivial point group of QCs favors them as physical QLs.

5. Expanding hyperbolic tessellations and quasi-tessellations obtained by embedding $H^3 \subset M^4$ to $H^7 \subset M^8$

M^8-$M^4\times CP_2$ duality and the discretization required by the notion of p-adic manifold relates in an interesting manner to expanding hyperbolic tessellations and quasi tessellations in $H^7 \subset M^8$, and possible expanding quasi-tessellations in obtained by embedding $H^3 \subset M^4$ to $H^7 \subset M^8$

1. Euclidian lattices E_8, E_7, E_6

   I have already considered E_8 lattice in M^8. The background space has however Minkowskian rather than Euclidian metric natural for the carrier space of the E_8 lattice. If one assigns some discrete subgroup of isometries to it, it is naturally subgroup of $SO(8)$ rather than $SO(1,7)$. Both these groups have $SO(7)$ as a subgroup meaning that preferred time direction is chosen as that associated with the real unit and considers a lattice formed from imaginary octonions.

   E_8 lattice scaled up by a factor 2 to integer lattice allows octonionic integer multiplication besides sums of points so that the automorphism group of octonions: discrete subgroups of $G_2 \subset SO(7)$ would be the natural candidates for point groups crystals or lattice like structures.

If one assumes also fixed spatial direction identified as a preferred imaginary unit, G_2 reduces to $SU(3) \subset SO(6) = SU(4)$ identifiable physically as color group in TGD framework. From this one ends up with the idea about $M^8 - M^4 \times CP_2$ duality. Different embeddings of $M^4 \subset M^8$ are quaternionic sub-spaces containing fixed M^2 are labelled by points of CP_2.

All this suggests that E_7 lattice in time=constant section of even E^6 lattice is a more natural object lattice to consider. Kind of symmetry breaking scenario $E_8 \rightarrow E_7 \rightarrow E_6 \rightarrow G_2 \rightarrow SU(3)$ is suggestive. This Euclidian lattice would be completely anomalous to a slicing of 4-D space-time by 3-D lattices labelled by the value of time coordinate and is of course just what physical considerations suggest.

2. Hyperbolic tessellations

   Besides crystals defined by a cubic lattice or associated with E_6 or E_7, one obtains an infinite number of hyperbolic tessellations in the case of M^8. These are much more natural in Minkowskian signature and could be also cosmologically very interesting. Quite generally, one can say that hyperbolic space is ideal for space-filling packings defined by hyperbolic manifolds H^n/Γ: they are completely analogous to space-filling packings of E^3 defined by discrete subgroups of translation group producing packings of E^3 by rhombohedra. One only replaces discrete translations with discrete Lorentz transformations. This is what makes these highly interesting from the point of view of quantum gravity.

   (a) In M^{n+1} one has tessellations of n-dimensional hyperboloid H^n defined by $t^2 - x1^2 - ... - x_n^2 = a^2 > 0$, where a defines Lorentz invariant which for $n = 4$ has interpretation as cosmic time in TGD framework. Any discrete subgroup Γ of the Lorentz group $SO(1,n)$ of M^{n+1} with suitable additional conditions (finite number of generators at least) allows a tessellation of H^n by basic unit H^n/Γ. These tessellations come as 1-parameter families labelled by the cosmic time parameter a. These 3-D tessellations participate cosmic expansion. Of course, also ordinary crystals are crystals only in spatial directions. One can of course discretize the values of a or some function of a in integer multiples of basic unit and assign to each copy of H^n/Γ a "center point" to obtain discretization of M^{n+1} needed for p-adicization.

   (b) For $n = 3$ one has M^4 and H^3, and this is very relevant in TGD cosmology. The parameter a defines a Lorentz invariant cosmic time for the embeddings of Robertson-Walker cosmologies to $M^4 \times CP_2$. The tessellations realized as physical lattices would have natural interpretation as expanding 3-D lattice like structures in cosmic scales. What is new is that discrete translations are replaced by discrete Lorentz boosts, which correspond to discrete velocities and observationally to discrete red shifts for distant objects. Interestingly, it has been found that red shift is quantized along straight lines [E9]: "God's fingers" is the term used. I proposed for roughly two decades ago an explanation based on closed orbits of photons around cosmic strings [K31]. but explanation in terms of tessellations would also give rise to periodicity. A fascinating possibility is that these tessellation have defined macroscopically quantum coherent structures during the very early cosmology the size scale of H^3/Γ was very small. One can also ask whether the macroscopic quantum coherence could still be there.

   Hyperbolic manifold property has purely local signatures such as angle surplus: the very fact that there are infinite number of hyperbolic tessellations is in conflict with the fact that we have Euclidian 3-geometry in every day length scales. In fact, for critical cosmologies, which allow a one-parameter family of embeddings to $M^4 \times CP_2$ (parameter characterizes the duration of the cosmology) one obtains flat 3-space in cosmological scales. Also overcritical cosmologies for which $a = constant$ section is 3-sphere are possible but only with a finite duration. Many-sheeted space-time picture also leads to the view that astrophysical objects co-move but do not co-expand so that the geometry of time=constant snapshot is Euclidian in a good approximation.

3. Does the notion of hyperbolic quasi-tessellation make sense?

Can one construct something deserving to be called quasi tessellations (QTs)? For QCs translational invariance is broken but in some sense very weakly: given lattice point has still an infinite number of translated copies. In the recent case translations are replaced by Lorentz transformations and discrete Lorentz invariance should be broken in similar weak manner.

If cut and project generalizes, QTs would be obtained using suitably chosen non-standard embedding $M^4 \subset M^8$. Depending on what one wants to assume, M^4 is now image of M^4_{st} by an element of $SO(1,7)$, $SO(7), SO(6)$ or G_2. The projection - call it P - must take place to M^4 sliced by scaled copies of H^3 from M^8_{st} sliced by scaled copies of H^7/Γ tessellation. The natural option is that P is directly from H^7 to $H^3 \subset H^7$ and is defined by a projecting along geodesic lines orthogonal to H^3. One can choose always the coordinates of M^4 and M^8 in such a way that the coordinates of points of M^4 are $(t,x,y,z,0,0,0,0)$ with $t^2-r^2=a_4^2$ whereas for a general point of H^7 the coordinates are $(t,x,y,z,x_4,...x_7)$ with $t^2-r^2-r_4^2=a_8^2$ for $H^3 \subset H^7$. The projection is in this case simply $(t,x,y,z,x_4,...,x_7) \to (t,x,y,z,0,...,0)$. The projection is non-empty only if one has $a_4^2-a_8^2 \geq 0$ and the 3-sphere S^3 with radius $r_4=\sqrt{a_4^2-a_8^2}$ is projected to single point. The images of points from different copies of H^7/Γ are identical if S^3 intersects both copies. For r_4 much larger than the size of the projection $P(H^7/\Gamma)$ of single copy overlaps certainly occurs. This brings strongly in mind the overlaps of the dodecagons of Penrose tiling and icosahedrons of 3-D icosahedral QC. The point group of tessellation would be Γ.

4. Does one obtain ordinary H^3 tessellations as limits of quasi tessellations?

   Could one construct expanding 3-D hyperbolic tessellations H_3/Γ_3 from expanding 7-D hyperbolic tessellations having H^7/Γ_7 as a basic building brick? This seems indeed to be the outcome at at the limit $r_4 \to 0$. The only projected points are the points of H^3 itself in this case. The counterpart of the group $\Gamma_7 \subset SO(1,7)$ is the group obtained as the intersection $\Gamma_3 = \Gamma_7 \cap SO(1,3)$: this tells that the allowed discrete symmetries do not lead out from H^3. This seems to mean that the 3-D hyperbolic manifold is H^3/Γ_3, and one obtains a space-filling 3-tessellation in complete analogy for what one obtains by projecting cubic lattice of E^7 to E^3 imbedded in standard manner. Note that $\Gamma_3 = \Gamma_7 \cap SO(1,3)$, where $SO(1,3) \subset SO(1,7)$, depends on embedding so that one obtains an infinite family of tessellations also from different embeddings parametrized by the coset space $SO(1,7)/SO(1,3)$. Note that if Γ_3 contains only unit element $H^3 \subset H^7/\Gamma_7$ holds true and tessellation trivializes.

Do Penrose tilings correspond to edge paths of Bruhat-Tits tree for projective sphere $P^1(Q_p)$?

Perhaps it deservers to be mentioned that there is an amusing co-incidence with Penrose tilings (see the book "In search of the Riemann zeros" [A30] by Lapidus, page 200) and between the representation of 2-adic numbers. This representation is in terms of a a tree containing only 3-vertices. Incoming edge represents n: th binary digit in the expansions $x=\sum x_n 2^n$, $x_n=0,1$ and the two outgoing edges corresponds to the two values of the $n+1$: th binary digit. Each 2-adic number corresponds to a one particular edge path in this semi-infinite tree. This structure is very much analogous to Bruhat-Tits tree for p-adic projective line $P^1(Q_p)$ [A10] discussed in [K120].

A given Penrose tiling corresponds to semi-infinite bit string having only non-negative pinary digits and could be seen as a 2-adic integer. Two bit sequences describe same tiling if they differ from each other for a finite number bits only. Could the ends for the analog of Bruhat-Tits tree for p-adic integers (half-infinite paths beginning from some bit) be in one-one correspondence with Penrose tilings! Could one really describe 2-D Penrose tilings 2-adically? What about more general Penrose tilings and QCs? Maybe this conjecture is trivially true since Lapidus, who mentions this description of Penrose tilings, has written his book about p-adic strings [A30].

Unfortunately, I do not understand the arguments leading to the representation of Penrose tilings using bit sequences and whether this co-incidence has some deeper meaning.

10.8 Quantum self-organization by h_{eff} changing phase transitions

Hermann Haken [B23, B22] and Ilya Prigogine citebthePrigogine are two well-known pioneers of self-organization theories. The most important aspects of self-organization and non-equilibrium thermodynamics from TGD point of view are following.

1. The notion of thermodynamical non-equilibrium state is central. Temperature T is not anymore constant and varies in the system and also with time. Already Carnot cycle (see `http://tinyurl.com/ntk9a3k`) involving the system and environment at different temperatures can be regarded as a thermodynamical non-equilibrium state.

2. Thermal non-equilibrium states are generated in presence of energy feed. Otherwise the system would end up to a complete thermal equilibrium without any structure. These non-equilibrium states correspond to self-organization patterns.

3. The character of non-equilibrium states changes at critical points at critical values of parameters - say temperature, external magnetic field, or energy feed. Ordinary phase transitions could be seen as special cases of non-equilibrium phase transitions. If the flow of energy increases in transition, a more complex pattern with a longer coherence length is created. Long range fluctuations accompany the transitions.

4. Master-slave hierarchy is also a central notion. One can say that the master controls the dynamics of the slave in long time and length scales by providing a slowly varying background.

The TGD based model for biological self-organization relies on the hierarchy $h_{eff} = nh_0$ of effective Planck constants labelling dark phases of ordinary particles residing at magnetic flux quanta [L38, L40, L45] [K78, K77]. This model generalizes and suggests the replacement of non-equilibrium thermodynamics as basis of self-organization with its quantum variant based on dark matter hierarchy. The challenge is to formulate basic thermodynamical notions like work in terms TGD based quantum theory relying on zero energy ontology (ZEO) [K63].

The basic mechanism would be a phase transition creating dark matter phase as a Bose-Einstein condensate like state with particles having identical conserved quantum numbers. Conservation laws would force the ordinary matter to have opposite total charges. For instance, in the case of work one has momentum or angular momentum as a conserved charge. In the case of charge separation and high Tc superconductivity it would be em charge. Even color charges can correspond to conserved charges in TGD framework allowing scaled variants of strong interaction physics.

Basic biological functions involving the notion of work and also the formation of sensory percepts would rely on this mechanism. Also the ZEO based theory of consciousness predicting the change the arrow of time in ordinary state function [L34] reduction plays a central role and a model of nerve pulse is discussed as an example.

10.8.1 TGD inspired quantum theory of self-organization

The basic observation is that in zero energy ontology (ZEO) [K63] TGD can be formally regarded as square root of thermodynamics. Whether this reduces thermodynamics to quantum theory in the sense that moduli squared for the state function - basically mode of classical spinor field in the "world of classical worlds" (WCW) gives thermodynamical partition function in some situations is not however clear.

1. The square root of thermodynamical partition function would be defined by complex square roots of Boltzmann weights identified as products $exp(-E/2T)U$ of square root of the ordinary Boltzmann exponential and phase factor U. Also the vacuum functional in WCW [K88] [L56] is analogous to square root of partition function.

2. In TGD field patterns are replaced by preferred extremals of action as analog of Bohr orbit connecting 3-surfaces at the boundaries of causal diamond (CD). This space-time surface exists only for preferred pairs of 3-surfaces. In quantum field theory (QFT) action exponential

defined mere phase and is is formally analogous to Boltzmann weight: one has a formal analog of thermodynamics in the space of 4-D field patterns.

Action exponent contains now also real part so that one has functional integral instead of path integral. In fact, one has discrete sum over preferred extemals for a finite cutoff defined by discrete cognitive representations required by adelic physics [L31, L32, L50, L51]. Integrability of TGD strongly suggests that this occurs effectively also for the continuum theory: sum would correspond now to sum over maxima of Kähler function with functional integral performed around its small deformations.

This picture suggests a generalization of non-equilibrium thermodynamics to quantum level based on the hierarchy of effective Planck constants $h_{eff} = nh_0$ [L28, L45] labelling the phases of dark matter in TGD sense.

1. The value of n is identified as the dimension of extension of rationals inducing in turn extensions of p-adic number fields and extension of adele. Reals and p-adic number fields form adele as a book like structure with pages labelled by reals and extensions of various p-adic number fields induced by the extension of rationals. The extension of rationals defines the back of the book as the intersection of its pages.

   At space-time level the back corresponds to the points of embedding space with the values of preferred coordinates of embedding space in the extension of rationals and thus common to reals and all p-adic number fields. Preferred coordinates are unique apart from time translation in M^8 picture and apart from isometries of H in $H = M^4 \times CP_2$ picture [L30, L54, L53].

2. The books corresponding to all extensions of rationals form an infinite library. In quantum jumps the dimension of the extension is bound to increase since the number of extensions with dimension D smaller than given integer n is finite and the number of those with $D > n$ is infinite. Since the algebraic complexity of the extension increases with n, one can interpret this as evolution. In p-adic sectors one has cognitive evolution with n serving as "IQ". The increase of n means increase of quantum coherence lengths. The coherence of ordinary bio-matter would be forced by the quantum coherence dark matter with large value of n.

3. At the limit when the extension approaches algebraic numbers, the points of the cognitive representation form a dense subset of the space-time surface so that this corresponds to the optimal situation. I have conjectured that the roots fo Riemann zeta (see `http://tinyurl.com/nfbkrsx`) are algebraic numbers. A stronger conjecture would be that the roots of ζ span algebraic numbers. This would give to Riemann Zeta a completely unique role in mathematics. One can however argue that since the generalization of Riemann zeta as Dedekind zeta function exists for all extensions of rationals, this might not be true.

This suggests the following view about quantum self-organization.

1. Thermodynamical non-equilibrium states are replaced with zero energy states. Partition function is replaced with its square root having interpretation as a ground state wave function. This picture should be consistent with non-equilibrium thermodynamics.

   The density matrix characterizing ordinary space-like entanglement would be analogous to the ordinary density matrix. ZEO brings as a new element time like quantum entanglement between the quantum states associated with 3-surfaces at the two light-like 3-surfaces connected by preferred extremal. This entanglement is consistent with Lorentz invariance. By summing in the modulus squared of the amplitude (mode of WCW spinor field) over the states associated with 3-surfaces at second boundary of CD one obtains density matrix essential in p-adic thermodynamics involving superposition over massless states and states with non-vanishing mass squared.

2. Master slave hierarchy is replaced with the dark matter hierarchy as a hierarchy of adelic physics labelled by extensions of rationals defining p-adic length scale hierarchy in terms of preferred p-adic primes identifiable as ramified primes of the extension [L21, L55]. Given level with extension having dimension $h_{eff}/h_0 = n$ serves as a master for the levels $m < n$ with

m dividing n so that one has hierarchy consisting of extensions of extensions of.... Extension with dimension n would be extension of extension having dimension m. Quantum coherence of dark matter assumed to reside at magnetic flux tubes and sheets of the magnetic body (MB) would force the coherence of the ordinary matter.

All self-organizing systems would reflect the presence of h_{eff} hierarchy, not only the living systems. Once one has coherence in macroscopic length scale, one knows that there must be quantum coherence of dark matter at MB having onion-like structure with layers labelled by p-adic length scales in corresponding and/or longer length scales.

The additional hypothesis $\hbar_{eff} = \hbar_{gr} = GMm/v_0$, where $\hbar_{gr}$ is gravitational Planck constant introduced by Nottale [E6]. M is large mass -say the mass of Earth or Sun - and m small mass such as elementary particle mass, and $v_0 < c$ is velocity parameter makes possible macroscopic quantum coherence in long length scales.

In accordance with Equivalence Principle gravitational Compton length $\Lambda = \hbar_{gr}/m = GM/v_0$ does not depend on m. Also cyclotron energies $\hbar_{gr}eB/m = GMeB/v_0$ are universal having no dependence on m. The proposal is that the dark photons have energy in visible and UV range (at least) and that they can transform in energy conserving manner to ordinary photons interpreted as bio-photons [K15]. Gravitation would be involved with large values of $h_{eff} = h_{gr}$ implying macroscopic quantum coherence. This is natural since gravitation is not only long range interaction but also non-screened. Needless to say, this changes dramatically the vision about quantum gravitation as something appearing in Planck length scale.

3. In non-equilibrium thermodynamics energy feed is necessary. This is the case also now [L38]. Quite generally, the energies of the dark quantum states increase with h_{eff}, when other parameters are kept constant. This requires energy feed to excite dark states and also to preserve them since dark states decay spontaneously to states with lower value of h_{eff} having a lower energy. This energy feed would correspond to the metabolic energy feed in bio-systems.

   Even the self-organization involved with the emergence of increasingly complex convection patterns in the heating of liquid could involve the hierarchy of Planck constants and the increase of the heating power would correspond to an evolution increasing the values of h_{eff} involved.

To sum up, dark matter would seen at the level of everyday physics and the idea about classical physics somehow emerging above some length scale would be completely wrong: quantum physics would be present in all scales.

10.8.2 Some challenges of quantum theory of self-organization

Quantum theory of self-organization as a square root of non-equilibrium thermodynamics must encounter several challenges.

1. One should understand quantum counterparts for various thermodynamical notions - mention only temperature and entropy. Modulus squared for ground state wave function would give thermodynamical partition function for the counterparts of thermodynamical states. The notions of temperature and entropy indeed emerge. p-Adic entanglement negentropies and their sum relating to cognition are also defined if the entanglement coefficients belong to an extension of rationals as indeed assumed in adelic physics [L31, L32].

2. Genuinely thermodynamical notions such as work and heat engines must be understood. Carnot's cycle is associated with the simplest heat engine and leads to an upper bound for the efficiency $\eta \leq \Delta T/T_{max}$ characterizing work - that is ordered energy - that can be extracted from thermal energy with breaking of second law of thermodynamics. Already in this case one has two different temperatures so that in strict sense one does not have thermodynamical equilibrium.

What could the quantum notion of work mean? The simplest example is a cylinder filled with gas. When heated it expands and does work. What happens at quantum level when work is done?

1. Work means generation of ordered energy so that the momenta for ordinary matter are parallel rather than random as for the feed of thermal energy. Dark matter should induce this coherence somehow. The simplest model is that a fraction of ordinary particles makes a phase transition to dark phase forming a Bose-Einstein condensate like state with parallel momenta with coherence length of the order of system size. Momentum conservation forces the ordinary matter to generate opposite total momentum and coherent motion is the outcome. The part of energy going to heating of ordinary matter corresponds to entropy and one should have $dE = TdS - pdV$.

2. This picture applies also to the work generating coherent rotation in macroscopic scales. In this case dark quantum coherent states with parallel spin or angular momenta would be formed and by angular momentum conservation force the formation of coherent rotation of ordinary matter.

3. Quite generally, energy and momentum as conserved quantum numbers can be replaced with energy and some other conserved quantum quantities such as angular momentum or charge. Quantum coherent states with dark particles having identical quantum numbers are generated and ordinary matter has opposite total quantum numbers by basic conservation laws.

   One can understand the phase transitions generating coherence in longer scales as an emergence of dark Bose-Einstein like states carrying total quantum quantum numbers with conservation forcing opposite total quantum numbers for the ordinary matter. Work can be seen as a process analogous to spontaneous magnetization with spin replaced with momentum or angular momentum. Even freezing, melting, spontaneous magnetization, etc.... might allow this description.

4. An interesting question is whether conservation law for some quantum number is always involved. For instance, water is known to involve at least two phases and TGD proposal is that the other phase(s) correspond to dark phases in which magnetic flux tubes carrying dark proton sequences identifiable as dark nuclei are involved: this could be due to Pollack effect [L15] [L15]. Charge separation would occur and the conserved charge would be electromagnetic charge.

Quite generally, the formation of a quantum coherent dark matter structure with large h_{eff} would be always behind the formation of coherent structure of ordinary matter: one would have forced coherence. Also energy feed would be essential.

Consider some examples.

1. Magnetization is a standard example about a phase transition and still far from well-understood. Magnetization would be due to the generation of dark matter at magnetic flux tubes inducing the magnetization. Conservation of spin and more generally angular momentum would be essential. Dark matter at the magnetic body (MB) of system would have spontaneous magnetization and parallel spins and angular momenta.

   Remark: No currents are needed to generate the magnetic field if the flux tubes carry monopole flux. TGD allows this since CP_2 is homologically non-trivial containing non-contractible 2-surface.

   Hysteresis curve representing magnetization of a ferromagnet as function of external magnetic field represents an interesting challenge for the model. The fraction of the dark phase varies along hysteresis curve and the magnetization process is not reversible.

   The description of antiferromagnetism is a challenge for this picture since in this case the total spin vanishes. Magnetic body as a network of flux tubes suggests that given flux tube behaves like dark ferromagnet inducing ferromagnetic subsystem by conservation of spin: the dark and ordinary spins would have nearly the same M^4 projection.

2. This picture applies also to the strange effects associated with rotating magnetic systems discovered by Godin and Roschin [H28] [K107]. The observed cylindrical flux sheets carrying rotating dark particles with non-vanishing total angular momentum would be spontaneously generated and ordinary matter - the rotating magnetic system - would generate opposite angular momentum.

   The source of the energy feed is not obvious: one possibility is that the energy comes from the magnetic energy of the rotating system or from the electrostatic fields involved. Also external source can be considered. Interestingly, the rotation accelerates as the rotation frequency of the motor approaches 10 Hz, which defines a fundamental bio-rhythm. Could it be that the energy feed comes from outside as dark photons with 10 Hz frequency but large energy?

3. Super-conductivity presents a second example. Cooper pairs are charged so that charge separation would be involved. If Cooper pairs correspond to ordinary particles, the model requires their transformation to dark Cooper pairs. In high Tc superconductivity Cooper pairs are formed at higher critical temperature T_{c_1} and supra currents become possible at lower critical temperature T_c [K79, K80]. Ordinary Cooper pairs could not have any coherent momentum in macroscopic scales above Tc. Dark Cooper pairs having parallel momenta would emerge at T_c and the ordinary Cooper pairs would receive an opposite momentum.

4. Tornado involves center at low pressure and temperature and there is heat flow from environment generating the rotation of the vortex which has lower velocity towards center so that the center is at rest. This would mean increased pressure by $p + \rho v^2/2 = constant$.

   The presence of magnetic fields in the vortex however generates magnetic pressure and energy so that one has $E_B + p + \rho v^2/2 = constant$. Hence p could be lower at the center and explains the effects of tornado. Temperature is also lower and also this is due to the magnetic energy. The magnetic field need not be electromagnetic. Long ranged Z^0 fields are indeed possible in TGD for large values of h_{eff} and one of the oldest proposals concerning hydrodynamics is that hydrodynamical vortices could correspond to Z^0 magnetic flux tubes. Only dark Z^0 magnetic flux tubes would be needed. In sunspots this indeed happens, which leads to ask whether magnetic spots could correspond to tornadoes. Also in Jupiter there is a red spot representing a permanent tornado.

   One can regard tornado as a quantum analog of Carnot's engine. Temperature difference between the exterior and the center corresponds to that in Carnot's engine and could be generated spontaneously by the generation of magnetic flux tubes: the quantum coherent rotation of dark particles at flux tubes forces the coherent motion of ordinary particles by angular momentum conservation.

5. In the case of ordinary hydrodynamical vortex there is no external energy feed and vortex created in some manner decays to smaller vortices. The interpretation would be as a cascade resulting as the value of h_{eff} decreases making the quantum coherence length smaller. Also now dark magnetic - or rather, Z^0 magnetic [K14] - flux tubes carrying dark particles could be present. The question whether Z^0 fields are present in long length scales is still open: chiral selection in living matter could be interpreted in terms of the presence of Z^0 fields in cellular length scales. Z^0 magnetic fields could be important also in super-fluidity and the conserved and quantized vorticity could correspond to Z^0 magnetic flux.

6. Ball lightning could be also seen as a simple self-organizing system. The energy of particles could come from the acceleration of charged dark particles at the magnetic flux tube involving very small dissipation explaining also the charged particles and gamma rays with anomalously high energies found to accompany lightnings. Also a charge separation giving rise to an analog of cell membrane like structure involving also charge separation would be involved.

10.8.3 Applications to TGD inspired quantum biology and consciousness theory

Living matter moves in various ways. The generation of dark matter condensates could explain how work is done in living matter. Living matter also perceives and dark matter condensates could also lead to the generation sensory qualia. In TGD framework sensory perception and motor action can be actually regarded as time reversals of each other [L41]. Libet's findings [J13] showing that volitional motor action such as raising index finger is preceded by neural activity supports the view that motor action generates time reversed state at some levels of the hierarchy of space-time sheets [L46].

Quantum engines in biology

Quantum engines building themselves by self-organization in presence of metabolic energy feed would be the key notion.

1. Muscle represents a basic example about a living system doing work. A toy model is as a structure consisting of n parallel vertical filaments of length L - such as flux tubes - forming a horizontal pile in vertical plane such that they can glide with respect to each other in vertical direction but cannot get loosen from each other. The minimum length of the configuration is L and maximal length is nL. The stretching of the muscle would be caused by a push of say right-most filament upwards and this motion would force other filaments to follow when the shift of this filament exceeds L. h_{eff} increasing ordinary-to-dark phase transition for the associated flux tubes would generate Bose-Einstein condensate with particle in the same direction. By momentum conservation the filament receives an opposite momentum.

2. ATP machinery (see `http://tinyurl.com/ovhk94j`) involves ATP synthase, which can be regarded as a molecular motor with a rotating shaft. Each turn of this motor creates ATP from ADP. This requires energy feed obtained as protons accelerate through the membrane potential gradient and give their energy to the rotation of the shaft and to the chemical energy of ADP. The energy of protons comes from electron transport chain and is provided by metabolite. The angular momentum of the shaft would be generated by the conservation of angular momentum in the formation of dark Bose-Einstein condensates with bosons carrying parallel angular momenta. The H^+ motors driving flagella would work in very similar manner.

   An interesting question concerns the nature of the Bose-Einstein condensates involved in the process.

3. In cell membrane ions are pumped against gradient of electric field. This requires energy and work must be done. The proposed general quantum mechanism for work explains how the work could done at quantum level.

4. One can consider also charge separation as similar quantum phenomenon with conserved momentum replaced with conserved em charge. Pollack effect occurs in presence of energy feed - such as IR photons - and generates negatively charged regions - exclusion zones (EZs) in water bounded by organic matter. The TGD based model [L15] assumes that protons are transferred to magnetic flux tubes, where they form dark protons sequences having interpretation as dark nuclei [L19, L29]. This would be both fundamental mechanism of pre-stellar evolution and biology. For instance, negatively charged DNA (each nucleotide is charged) would be accompanied by dark DNA consisting of sequences of dark protons with 3-proton units providing a realization DNA, RNA, tRNA and amino-acid states and also vertebrate genetic code [L25, L36].

   The formation of cell membranes involving charge separation with negative charge in cell interior could also involve Pollack effect making possible pumping of protons and also other charge particle to generate membrane potential in the presence of metabolic energy feed realized as ordinary photons. Also spontaneous formation of lipid layers - also of soap films - could be this kind of process.

Quantum model for nerve pulse

In TGD based model of nerve pulse axonal membrane is generalized cylindrical Josephson junction defined by axonal membrane consisting of smaller Josephson junctions defined by membrane proteins.

1. A sequence of mathematical penduli along axon in rotation in the same direction is the mechanical analog. Oscillation frequency Ω transforming to a rotation frequency above critical value is proportional to the resting potential V. When V is overcritical, the pendulum starts to rotate instead of oscillating. The system should be near quantum criticality for the transformation of rotation to oscillation or vice versa.

2. During nerve pulse membrane potential and therefore also rotation frequency is reduced and changes sign and then returns back to the original value. The first guess is that at criticality there is a kick reducing the rotation frequency Ω and continuing to change its sign and then return it to original.

The basic condition is that resting state becomes critical at critical hyper-polarization. There are two options for the resting state.

1. According to the original model [K82], resting state can be regarded as a soliton sequence associated with the phase difference over the membrane. More concretely, the mathematical penduli rotate in same direction with phase difference between determining the propagation velocity of solitons. The rotation frequency is slightly above that for oscillation. There is a preferred direction along axon. This conforms with the reduction and change of sign of potential and thus of Ω.

   Problem: Hypo- rather than hyper-polarization should cause the nerve pulse as a transformation of rotation to oscillation. Something goes wrong.

2. Alternatively, the penduli almost rotate being near criticality for the rotation: the penduli almost reaches the vertical position at each oscillation as required by criticality. That hyper-polarization would cause the nerve pulse as propagating soliton conforms with this idea.

   Problem: Ω and thus V should increase rather than reduce and even change sign temporarily.

Neither option seems to work as such but the first option is more plausible as a starting point of an improved model.

The membrane potential changes sign suggesting quantum jump. Could zero energy ontology (ZEO) based view about quantum jump as "big" (ordinary) state function reduction (BSFR) help? Could nerve pulse correspond to BSFR?

1. Could BSFR occur changing temporarily the arrow of time in ZEO and induce nerve pulse. Could opposite BSFR take place after this in millisecond scale and establish the original arrow of time. Using the language of TGD inspired theory of consciousness [L34], a conscious entity, sub-self or mental image, would die and reincarnate with an opposite arrow of time, live for the duration of nerve pulse and then die and reincarnate with the original arrow of time. Nerve pulse would be a propagation of a temporary neuron death along the axon and would occur as neuron becomes hyper-polarized.

2. In the article [L46] about the recent findings of Minev *et al* [L46] related to quantum jump in atomic physics are discussed. ZEO predicting that the arrow of time is changed in BSFR. This would create the illusion that discontinuous quantum jumps correspond to a classical time evolution leading smoothly and deterministically to the final state.

   This because BSFR leads to a state with reversed arrow of time, which corresponds to a superposition of classical time evolutions leading from the final state to the geometric past and it this, which is observed. This would also explain why the removal of the irradiation inducing quantum jumps has no effect during the transition process and why a stimulation inducing opposite quantum jump can stop the process. Also the findings of Libet related to the active aspects of consciousness [J13] showing that neural activity seems to preceded volitional act can be understood in this framework without giving up the notion of free will.

   The first half of the nerve pulse would correspond to this apparent evolution to the time reversed final state with opposite membrane potential but actually being time reversed evolution from the final state. The second half of nerve pulse would correspond to opposite state function reduction establishing the original arrow of time. This model looks attractive but many details remain to be checked.

Why hyper-polarization should cause the temporary death of neuron or its subself?

1. Metabolic energy feed is needed to preserve the polarization of neuron since membrane potential tends to get reduced by second law stating that all gradients are bound to decrease. There should be some maximal polarization possible to preserve using the existing metabolic energy resources.

2. Does quantum jump to a state with opposite arrow of time happen as this limit is reached? Why? Could the metabolic energy feed stop causing the neuron to die to starvation? Why the death of neuron should happen so fast? Could the quantum criticality against the change of rotation to oscillation be the reason. When neuron cannot rotate anymore it would die immediately: the mental image "I am rotating" would die and reincarnate as its time reversal. Does the neuron feeded by metabolic energy become a provider metabolic energy during this period somewhat like dead organisms after their death. Can one conclude that this energy goes to some purpose inside neuron?

Sensory perception and qualia

Sensory perception (time reversal of motor action [L41]) could involve generation of coherent phases of dark matter carrying collective quantum numbers in 1-1 corresponds with the sensory qualia. This would represent a general charge separation process.

Consider first sensory capacitor model for color qualia [K41].

1. The notion of QCD color as analog of ordinary visual colors was originally introduced as a joke since the algebra of color summation resembles that for the summation of QCD colors in tensor product. In TGD however the dark hierarchy (h_{eff}) and p-adic length scale hierarchy predict that scaled variants of QCD type physics are possible for arbitrarily large length scales. In cellular scales scaled up QCDs are predicted. In the length scale range between cell membrane thickness and nucleus size there are as many as 4 Gaussian Mersennes, which is a number theoretical miracle. They could label copies of QCDs with size scale for the analogs of hadrons given by the corresponding p-adic length scales. QCD type colors could correspond to perceived colors [K41] [L37].

2. Gluons or quarks labelled by color charge characterizing particular color quale would flow between the plates of "capacitor" associated with the sensory receptor. The amount of particular color charge increases at the other plate giving rise to sensation of this particular color quale and its complement at the other plate - by color confinement also the same plate could also contain regions with complementary colors. This would explain why we see around a region of particular color a narrow boundary with complementary color.

3. The model for sensory perception as sequences of analogs of weak measurements suggest that the flow of color charges could induce color qualia. The prediction emerging from the structure of SU(3) color algebra would be four pairs of basic color and complement color: 3 ordinary pairs and white-black pair. They could correspond to particular changes of color quantum numbers and color quantum numbers of gluons. Also color mixing could be understood.

4. Photons are not coloured but gluons (and also quarks) are, and the latter and could be responsible for color sensation. How photon flux can generate a flow of color quantum numbers? The notion of induced gauge field -classical color gauge potentials would be projections of $SU(3)$ Killing vectors - explains this.

   In TGD classical em field is sum of two terms induced Kähler form and neutral vectorial component of spinor curvature [L2]. Classical gluon field has components proportional to classical color Hamiltonian (function in CP_2 which can be said to have quantum numbers of gluon) and induced Kähler form. In general case any classical em field is accompanied by a classical color field.

   Photons are accompanied by classical em fields and therefore also by classical gluon fields at the fundamental level: this correspondence disappears at QFT limit unable to describe biology and sensory experience. The flow of photons to retina would be accompanied by classical em and color fields and therefore a flow of gluons. Also quark flow between the plates of sensory capacitor could generate the color qualia.

5. A simple model for the visual qualia is in terms of a phase transition transforming gluons of a scaled copy of QCD to ordinary gluons. Dark gluons would form a BE condensate and force a formation its shadow at the level of ordinary matter. This is a variant of sensory receptor as quantum capacitor. The plates of capacitor correspond to dark and ordinary phase and the analog of electric breakdown means formation of the dark phase. Cooper pairs of quarks with quantum numbers of gluon would be second option but gluons in TGD framework are actually this kind of pairs!!

Hearing [K81] as a quale could be associated to a generation of dark variants of vibrating flux tubes connecting molecular or larger structures. The variation of the length of flux tube would be fundamental representation for the quale of hearing. Also now Bose-Einstein condensate like state would be involved but it is not quite clear what the conserved charge would be now: it could be that the collective excitations at dark level correspond to those at the level of ordinary matter. At even more fundamental level the vibrations of fermionic strings assignable to the 2-D string world singularities of space-time surfaces (at which minimal surface property fails since there is transfer of canonical momentum currents between Kähler action and volume term) would correspond to hearing quale.

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Chapter 11

Biological Realization of Self Hierarchy

11.1 Introduction

The understanding of the biological systems from the first principles seems to be an almost insurmountable task. These systems are both structurally and functionally extremely complicated and the existing basic physics doesn't offer very many obvious clues as how one might understand the generation of the spatial and temporal structures from the first principles. In fact, it is not at all obvious whether the first principles are even known. The standard reductionistic and materialistic world view combined with the notion of linear time is extremely restrictive framework and might simply not allow life and consciousness.

TGD and TGD inspired theory of consciousness has however led to a general conceptual framework, which differs radically from that of the standard physics. The highly nontrivial implication is that TGD inspired theory of consciousness provides, not only general insights, but very detailed ideas as regards to the structure and functioning of the living systems. In this chapter the emphasis is more on structure whereas the next chapters entitled "Quantum Control and Coordination in Bio-Systems: part I/II" [K73, K72] concentrate on the functional aspects.

11.1.1 The Notions Of Self And Self Hierarchies

The breakthrough idea in TGD inspired theory of consciousness was the notion of self defined as a subsystem able to remain unentangled during the unitary quantum "time evolutions" U associated with quantum jumps $\Psi_i \rightarrow U\Psi_i \rightarrow \Psi_f$. The notion of self leads to the concept of self hierarchy and the interpretation of quantum self-organization as evolution of selves [K87].

What self actually is in quantum sense, has taken long time to understand. The realization that in zero energy ontology (ZEO) sequences of repated quantum jumps leave only the second half of zero energy state invariant but change the other one led to the identification of self as the sequence of the quantum jumps reducing the state to the same boundary of causal diamond (CD). This differs from the original identification in which repeated quantum jumps played no role. This also answers basic questions about the relationship of geometric and subjective time allowing to understand how the flow and arrow of geometric time emerge predicting also that it can change.

Zero energy ontology implies that quantum states correspond to physical events in standard ontology. This means that self has extension in time direction and has causal diamonds (CDs) defined as intersections of future and past directed light-cones as embedding space-time correlates and space-time sheets within CDs as space-time correlates. Self corresponds therefore to a finite-sized object in both spatial and temporal directions and can be seen as a classical self-organization pattern at space-time level. Quantum jumps replace this pattern gradually with an asymptotic self-organization pattern.

The infinite size of the universe forces to introduce the notion of infinite primes and corresponding p-adic topologies. Infinite primes have decomposition into finite primes labelling space-time sheets possessing p-adic topology. The notion of infinite prime allows to understand continuous evolution of physical systems as increase of the finite p-adic prime associated with them as also discontinuous processes in which entirely new p-adic space-time sheets emerge. The gradual increase of the cell size during evolution and emergence of multicellular structures provide examples of the two aspects of the evolution. The increase of the finite prime corresponds to gradual refinement of the corresponding p-adic topology in the sense that the notion of nearness as it is realized at the level of conscious experience becomes more and more refined. Also the maximum information content of conscious experiences increases with p-adic prime. Thus a measure for the complexity of a conscious system is in question.

The observation that Shannon entropy allows an infinite number of number theoretic variants for which the entropy can be negative in the case that probabilities are algebraic numbers leads to the idea that living matter in a well-defined sense corresponds to the intersection of real and p-adic worlds. This would mean that the mathematical expressions for the space-time surfaces (or at least 3-surfaces or partonic 2-surfaces and their 4-D tangent planes) make sense in both real and p-adic sense for some primes p. Same would apply to the expressions defining quantum states. In particular, entangleement probabilities would be rationals or algebraic numbers so that entanglement can be negentropic and the formation of bound states in the intersection of real and p-adic worlds generates information and is thus favored by NMP. The proposal is that the generation of negentropic bound state entanglement does not lead to a loss of consciousness unlike the generation of negentropic bound state entanglement can do. The need to remain conscious and even expand consciousness would favor co-operation and sharing instead of selfish fight for survival. Dissipation would still serve as the Darwinian selector.

11.1.2 Selves Self-Organize

A system possessing self (possibly having sub-selves) performs quantum jumps and dissipates. This leads to quantum self organization leading to asymptotic patterns selected by dissipation, which thus acts as a Darwinian selector of both memes and genes. Actually, there is no deep difference between genes and memes (understood here rather metaphorically) since selves are always conscious systems and consciousness is present already at elementary particle level. Furthermore, the zero energy states themselves have meme like properties. For instance, the many fermion states associated with positive and negative energy parts of the states have interpretation in terms of elements of Boolean algebra so that states define logical rules $A \rightarrow B$ with various instances of A and B appearing as pairs of positive and negative energy fermion stats in the quantum superposition. In light of this the notion of the self hierarchy should be of crucial importance for the understanding of living systems and the purpose of this chapter is to demonstrate this and also to propose a general view about how biological self hierarchy is realized.

ZEO brings new important aspect to self-organization. The usual approach to 3-D asymptotic self-organization is replaced with approach to 4-D self-organization pattern associated with CD since 3-surface is replaced with a pair of space-like 3-surfaces associated with the opposite boundaries of CD (also light-like partonic 2-surfaces might be included). This meas that asymptotic pattern, which corresponds to a maximum of Kähler function defining a spatio-temporal rather than only spatial pattern. This brings new insights about modelling biological processes such as protein folding, morphogenesis, and behaviors. Another new element is the notion of magnetic body in 4-D sense. Replication is fundamental process in biology and can be understood as analog of particle decay in which magnetic body in 3-D sense replicates.

11.1.3 Massless Extremals

Space-time sheets having their ends at the opposite light-like boundaries of CDs have finite temporal duration in zero energy ontology and provide representations of the material world. They serve as geometrical correlates of selves and biological self hierarchy reduces geometrically and topologically to a hierarchy of space-time sheets related to the hierarchy of CDs. within CDs. Crucially involved is the notion of topological field quantization, which implies that also photons have as their geometrical correlates so called topological field quanta.

Electromagnetic (em) fields and their topological field quanta are expected to be especially important in bio-systems. One possible interpretation for the topological field quanta of em field is as classical/quantal coherence regions of classical/quantum em field. ELF (extremely low frequency) em fields are known to have dramatic effects on living matter and brain and the origin of these effects is poorly understood. A simple argument based on Uncertainty Principle leads to the conclusion that ELF photons in 10 Hz frequency range correspond to topological field quanta of size of entire Earth! This leads to a rather dramatic conclusion that our biological body is only a dip of an iceberg and we are much more than our neurons. The most important levels in our personal self hierarchy contains levels are of size of Earth!

The so called massless extremals (MEs) are excellent candidates for the topological field quanta of radiation fields. They allow at their light like boundaries representations of super-conformal and super-symplectic algebras with gigantic state degeneracies broken only by gravitation. These states are genuinely quantum gravitational states in the space of 3-surfaces ("world of worlds") and thus in a well-defined sense correspond to a higher level of abstraction. By general coordinate invariance these states define quantum holograms and are excellent candidates for coding biological information. The properties of MEs make them also ideal for holographic quantum teleportation. Also the quantum model of qualia relies on the quantum phase transitions for super-symplectic representations [K41, K85].

11.1.4 Hierarchy Of Super-Conducting Magnetic Flux Tube And Electret Structures

All magnetic flux structures associated with body could be of crucial importance for understanding human consciousness. For instance, eyes generate magnetic fields. Also brain, in particular pineal gland (the "third eye" of mystics and the seat of soul for Descartes), contains magnetic materials. Corresponding magnetic transition frequencies correspond to time scales relevant for the self narrative in human time scales. Perhaps these higher levels of magnetic self hierarchy could relate with NDE experiences and represent structures surviving in physical death. It took some time to realize that magnetic flux tubes have the flux quanta of electric field as dual solutions of the field equations. Bio-system is indeed populated by various electret structures, mention only micro-tubuli and cell membrane as examples.

11.1.5 Living Matter As Symbiosis Of MEs, Super-Conducting Magnetic Flux Tube Structures, Electrets And Ordinary Matter

This picture leads to a view about living matter as a symbiosis of the fractal hierarchies of MEs and super-conducting magnetic flux tube structures and electrets with ordinary bio-matter at atomic space-time sheets. Bio-control is based on many-sheeted ionic flow equilibrium and magnetic quantum phase transitions allowing very effective control of biochemistry. The interactions between MEs and super-conducting ions are standard interactions between em fields and super-conductors (magnetic induction, induction of Josephson currents, magnetic phase transitions).

In the following the most recent (and still developing) TGD inspired view about biological self hierarchy is described and the possible consequences are considered at various length scales. For the reader willing to learn about the general ideas relating to self and self hierarchy, the references [K58, K89] of [K105] are recommended.

11.1.6 TGD Based View About Dark Matter

Self-hierarchy is the basic prediction of the TGD inspired theory of consciousness and the biological realization of the self-hierarchy is the basic theme of this chapter. Space-time sheets, in particular mind like space-time sheets having finite temporal duration and providing cognitive representation of the material world, are geometrical correlates of selves and biological self hierarchy reduces geometrically and topologically to the hierarchy of space-time sheets. Crucially involved is the notion of the topological field quantization, which among other things implies that photons have as their classical geometrical correlates so called topological field quanta. One interpretation for the topological field quanta of em field is as classical/quantal coherence regions of classical/quantum em field and electromagnetic (em) fields and their topological field quanta are expected to be especially important in bio-systems. One can assign vacuum quantum numbers to topological field quanta and these quantum numbers are expected to be carriers of a biologically relevant information.

What self actually is in quantum sense, has taken long time to understand. The realization that in zero energy ontology (ZEO) sequences of repated quantum jumps leave only the second half of zero energy state invariant but change the other one led to the identification of self as the sequence of the quantum jumps reducing the state to the same boundary of causal diamond (CD). This also answers basic questions about the relationship of geometric and subjective time.

In principle the self hierarchy starts already at elementary particle level but the atomic length scale serves as a natural length scale for length scale at which biological relevant part of the self-hierarchy starts.

1. The assumption that various bio-molecules are selves allows to understand the miraculous abilities of living systems as outcome of quantum self-organization process in which dissipation selects very limited repertoire of self-organization patterns identifiable as survivors in Darwinian selection. For instance, one can understand protein folding and DNA replication as self-organization processes. The 4-D character of self-organization implies that the most probable outcomes are pairs of 3-surfaces at boundaries of causal diamond defining spatio-temporal rather than only spatial pattern. This allows totally new view about morphogenesis and development of skills.

2. The fact that bio-systems are liquid crystals, makes them ideal for the realization of the self hierarchy. The reason is that liquid crystals have ability to self-organize to very complicated structures and are ideal for communication purposes: for instance, mechanical signals can be coded to electric signals and vice versa. Liquid crystals are also electrets: the presence of electric fields is indeed an important prerequisite of cognition in TGD as discussed in the chapter "Information and consciousness". In fact, one could identify various bio-structures such as micro-tubuli, cell organelles and cells as generic outcomes of the self-organization of the liquid crystals. An especially important level of the self hierarchy is provided by collagen networks which could give rise to what might be called "body consciousness". Central nervous system is only one, although very important level in the self hierarchy, and TGD approach allows to understand why this is the case.

3. p-Adic length scale hypothesis allows quantitative grasp to the structure of the self hierarchy and one can build general picture about how various p-adic length scales emerged during the evolution. In particular, one can identify various p-adic length scales associated with the brain.

4. One level of the self hierarchy corresponds to the topological field quanta of ELF em fields associated with EEG. ELF (extremely low frequency) em fields are known to have dramatic effects on living matter and brain and the origin of these effects is poorly understood. A simple argument based on Uncertainty Principle leads to the conclusion that ELF photons in 10 Hz frequency range correspond to topological field quanta of size of entire Earth. This leads to a rather dramatic conclusion that our biological body is only a dip of an iceberg and we are much more than our neurons. The most important levels in our personal self hierarchy contains levels are of size of Earth! Support for this picture come from the quantitative success of the scenario: one can immediately understand various important neuro time scales in terms of the cyclotron frequencies of various charged particles in Earth's magnetic field.

5. Each bio-structure is accompanied by a topologically quantized magnetic field defining corresponding magnetic body and these magnetic bodies form a hierarchy. Magnetic bodies could serve as intentional agents, as templates for the formation of various biological control circuits crucial for homeostasis and biological information processing, define the basic structure making possible metabolism with universal metabolic energy currencies, and could even define what might be called Nature's own bio-laboratory.

6. The magnetic flux structures associated with body could be of crucial importance for understanding human consciousness. For instance, eyes generate magnetic fields. Also brain, in particular pineal gland (the "third eye" of mystics and the seat of soul for Descartes), contains magnetic materials. Corresponding magnetic transition frequencies correspond to time scales relevant for the self narrative in human time scales. Perhaps these higher levels of

magnetic self hierarchy could relate with NDE experiences and represent structures surviving in biological death.

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` [L13].

11.2 Many-Sheeted Space-Time Concept And Living Systems

The notion of many-sheeted space-time is especially useful in the TGD based model living matter. Before continuing a warning is in order. The original view according to which space-time sheets have boundaries is not probably allowed by boundary conditions. The sheets are actually pairs of sheets glued together along the boundaries present otherwise. This conforms with the view about particles wormhole contact pairs with wormhole contacts (see **Fig.** `http://tgdtheory.fi/appfigures/wormholecontact.jpg` or **Fig. ??** in the appendix of this book) connecting two space-time sheets and carrying magnetic flux. In absence of this flux the wormhole contact is not stable.

11.2.1 Topological Field Quantization

Topological field quantization is a concept whose central importance in TGD has become only gradually clear. In the following some aspects of the topological field quantization are discussed. Super-conducting magnetic flux tubes and massless extremals (MEs) are especially important topological field quanta as far as quantum control is considered. MEs allow at their light like boundaries representations of super-conformal and super-symplectic algebras providing quantum hologram type representation of biological information with enormous state degeneracies. Since these representations have interpretation as genuinely quantum gravitational state functionals in the "world of classical worlds", they should correspond to higher level consciousness than the super-conducting BE condensates at magnetic flux tubes.

Topological field quantization as geometric counterpart of quantization

Topological field quantization [K51] implies that various notions of quantum field theory have rather precise classical analogies. Topological field quantization provides the correspondence between the abstract Fock space description of elementary particles and the description of the elementary particles as concrete geometric objects detected in the laboratory. In standard quantum field theory this kind of correspondence is lacking since classical fields are regarded as a phenomenological concept only. Topological field quanta define regions of coherence for the classical fields and classical coherence is the prerequisite of the quantum coherence.

The energies and other classical charges of the topological field quanta are quantized as preferred extremals of Kähler action making classical space-time surfaces the counterparts of the Bohr orbits. Feynman diagrams become classical space-time surfaces with lines thickened to 4-manifolds. For instance, "massless extremals" representing topologically quantized classical radiation fields are the classical counterparts of gravitinos and photons. Topologically quantized non-radiative nearby fields give rise to various geometric structures such as magnetic and electric flux tubes.

The virtual particles of quantum field theory have also classical counterparts. In particular, the virtual particles of quantum field theory can have negative energies: this is true also for the TGD counterparts of the virtual particles. The fundamental difference between TGD and GRT is that in TGD the sign of energy depends on the time orientation of the space-time sheet: this is due to the fact that in TGD energy current is vector field rather than part of tensor field. Therefore space-time sheets with negative energies are possible.

This could have quite dramatic technological consequences: consider only the possibility of generating energy from vacuum and classical signalling backwards in time along negative energy space-time sheets [K110, K39]. Also bio-systems might have invented negative energy space-time sheets: in fact, so called "massless extremals" (MEs) provide an ideal manner to generate coherent motions as recoil effects caused by the creation of negative energy massless extremals [K73, K72]. An interesting possibility is that quantum entanglement has the formation of the flux tubes as its geometric correlate.

The crucial question is of course "How to make this idea quantitative?". An attractive possibility is that topological field quanta identified as material or mind like space-time sheets could be regarded as counterparts of oscillator operators of free fields in quantum field theory. This would mean that one could make order of magnitude estimates for the probabilities for the presence of various numbers of both material and mind like space-time sheets using quantum field theoretical intuition. The coefficient of a particular state in the expansion of the creation operators of the outgoing interacting quantum fields in terms of the creation and annihilation operators of free quantum fields could provide an estimate for the probability that a particular configuration containing topological field quanta with positive and negative energies results in quantum jump between quantum histories. Since mind like space-time sheets are correlates for virtual particles, this would also mean a deep connection between quantum field theory and cognition.

Topological field quanta, in particular flux tubes of magnetic fields, could serve as templates for the formation of the bio-structures. Thus topologically quantized classical electromagnetic fields could be equally important for the functioning of the living systems as the structures formed by the visible bio-matter and the visible part of bio-system might represent only a tip of an ice berg.

Topological field quantization and classical de-coherence

The fact that topological field quanta correspond to coherence regions of classical field suggests that there must be a deep connection between classical de-coherence and space-time topology. This connection indeed exists. An innocent question of Claude Rifat concerning macroscopic classical coherence led me to realize that the nebulous phenomenon of de-coherence can be regarded as a direct evidence for the many-sheetedness of the space-time! In principle, the counting the number of in-coherent components of various fields gives an experimental method to deduce the number of space-time sheets present. The nature of de-coherence gives also information about the sizes of the space-time sheets and their durations! Thus everyday physics provides direct demonstration for the notion of the many-sheeted space-time: for some reason I had not realized this earlier. The detailed argument goes as follows.

1. Everything is classically coherent at basic level

Topological field quanta can be said to be coherence regions of classical fields, say em field. Typically frequency determines the size of the coherence region by Uncertainty Principle and topological field quanta of ELF em fields are huge: 10 Hz corresponds to the circumference of Earth. One can also say that everything is coherent at the level of the microscopic description. In TGD framework the loss of coherence is only a phenomenological manner to describe certain experimental facts in Maxwell's theory.

2. "Loss of coherence" provides direct evidence for topological field quantization!

In standard physics one has topologically trivial space-time containing classical fields: fields propagating to a given region just superpose. The predicted interference effects of two interfering classical fields are *not* always observed: this is called loss of coherence. As if superposed components would live in their own space-times so that interference is not possible so that energy and momentum densities are sums over the energy densities associated with these space-times. *This indeed the case in TGD! When two classical field sum in-coherently this means that they live on different space-time sheets and correspond to different topological field quanta* Classical coherence is also more or less equivalent with quantum coherence. The belief that physics does not allow macroscopic quantum coherence is illusion created by wrong space-time concept.

4. Phenomenological description of many-sheetedness as a loss of coherence

In Maxwell theory one describes the observed lack of interference effects due to many-sheetedness phenomenologically. The very definition of de-coherence is extremely problematic: one is forced to assume that measured quantities correspond to an ensemble or temporal averages and that the phases for the superposed fields vary randomly. This need not to be the case actually. Only when one builds effective description by replacing the entire many-sheeted space-time with ordinary space-time, one is forced to introduce linear superposition of various fields associated with various space-time sheet plus the nebulous notion of non-coherent superposition. At the level of many-sheeted space-time everything

5. Classical de-coherence is the counterpart for the loss of quantum coherence

By "Ontogeny Recapitulates Phylogeny Principle" (analogous to the corresponding biological principle), the loss of classical coherence is classical counterpart for the loss of quantum coherence occurring in quantum jumps. What this concretely means is that the initial quantum state, which is in general Fock state associated with single topological field quantum containing fermions and bosons, develops in time to a quantum superposition of states in which each fermion and boson resides at its own topological field quantum. This occurs already at the level of single quantum history. The occurrence of quantum jumps makes it possible to observe this since the sequence of quantum jumps increases the value of the psychological time of observer: sooner or later the final "de-cohered" state consisting of topological field quanta representing elementary particles is observed. It should be emphasized that quantum jump selecting one space-time surface from the superposition of space-time surfaces representing final state many particle configurations is a genuine element of this process: quantum jump cannot be reduced to classical physics.

11.2.2 Bio-System As A Topological Condensate With Several Important Space-Time Sheets

Topological condensate has hierarchical structure consisting of 3-surfaces with various sizes condensed on each other. In case of a bio-system several space-time sheet are expected to be important and to form a hierarchical information processing structure. Organic molecules belong to the lowest level of the hierarchy and correspond to 3-surfaces with outer boundary so that the association of the geometric form to molecules becomes much more than a convenient phenomenological modelling tool and leads to a new view concerning the understanding, say, the action of the organic catalysts. The topological condensation of the polymers to larger surfaces in turn gives rise to the formation of the cells, the topological condensation of the cells gives rise to the formation of the higher organs. In general, the vacuum quantum numbers tend to increase with the size of the structure.

p-Adic length scale hypothesis provides a precise quantitative formulation of the length scale hierarchy and predicts correctly several important biological length scales. In particular, the thicknesses for both the cell membrane consisting of two lipid layers and for the lipid layer appear in this hierarchy.

11.2.3 Topological Field Quantization And Dark Matter Hierarchy

The realization that the unavoidable hierarchy of long ranged classical color and electro-weak gauge fields at various space-time sheets is a space-time correlate for an infinite dark matter hierarchy and a hierarchy of color and electro-weak physics characterized by a p-adic hierarchy of weak and confinement length scales [?, K97, K38, K36] means that ordinary elementary particles are only a tip of an iceberg. For instance, the scope of the term "supra current" in TGD context becomes much wider than originally believed to be.

One might illustrate TGD Universe as being analogous to a Mandelbrot fractal. Just as each zooming in of Mandelbrot fractal reveals new worlds, each zooming out of TGD Universe reveals new universes for which the elementary particles of scaled down physics are lighter than at previous level and remain easily invisible for the previous level because the energies involved are so tiny. From the point of view of life and consciousness these subtle higher levels however represent the most essential aspects and we experience them directly.

Topological field quanta correspond to space-time correlates of particles at various levels of hierarchy. Wormhole contacts (# contacts) discussed in [?] and join along boundaries bonds ($\#_B$ bonds) connecting boundaries of holes at different space-time sheets mediate interactions between space-time sheets. # contacts can be modelled as CP_2 type extremals with an Euclidian signature of induce metric glued to the two space-time sheets with Minkowskian signature of induced metric. Wormhole contacts are thus accompanied by two light-like causal horizons having identification a partons. Thus # contacts represent an instance of an exotic dark matter residing simultaneously at two space-time sheets: this form of matter should be present in all length scales and could play decisive role in living matter [K121]. If the time orientations of two space-time sheets are opposite, these particles can have vanishing inertial energies. The splitting of # contacts gives rise to dark particles at the two space-time sheets involved.

The finding that the dark matter component of even astrophysical systems could be macroscopically quantum coherent and determine the properties of the visible matter to a high degree [K36] forces to seriously consider the possibility that living matter is much more than what is caught by eye. In particular, the notion of field body as a key concept in the attempts to understand of living systems finds additional support. The grand vision is that it is the presence of macroscopically quantum coherent dark matter hierarchy which makes "dead" matter living. The first attempt to deduce implications of this vision can be found in [K36] and a more detailed view is discussed in [K38].

11.2.4 Topological Field Quantization And Vacuum Quantum Numbers

Topological field quantization provides a TGD based first principle explanation for the emergence of the spatial structures. The size of the bio-structure depends on the vacuum quantum numbers [K51] and is dictated by the stability criteria implied by the minimization principle allowing to assign unique space-time surface to a given 3-surface, which is in general union of space-like 3-surfaces with time-like separations since the classical determinism in standard sense fails.

The hypothesis that bio-systems are super conductors in some sense implies that supra currents are a basic tool of the bio-control. The density of the charge carriers dictates the stable size and form of the organ and also the nontrivial phase information carried by the order parameter is expected to be important. There are handful of vacuum quantum numbers arising from the time and spatial behavior of the phase angles ϕ_i associated with the two complex CP_2 coordinates [K51]. One can express the dependence of these phase angles on space-time coordinates as a sum of Fourier expansion plus zero mode term linear in some coordinates and not allowing Fourier expansion. In linear Minkowski coordinates the vacuum quantum numbers behave like components of four-momentum. In spherical coordinates vacuum quantum numbers correspond to frequency, momentum in given direction plus integer analogous to the component of the angular momentum in the direction of momentum.

The set of vacuum quantum numbers associated with the two phase factors depends on the choice of the coordinates for M^4_+ and CP_2 and involves a selection of maximal number of mutually commuting observables in the Lie-algebras of Poincare group and color group. This is consistent with the fact that topological field quantization indeed is the classical counterpart of quantization. The construction of quantum TGD and understanding of the p-adic aspects of quantum TGD involves in an absolutely essential manner the choice of these quantization axes.

To fix the notation, the quantum numbers associated with the spherical coordinates will be denoted by (ω_i, k_i, n_i), $i = 1, 2$. detailed definitions of vacuum quantum numbers reader should consult the appendix of this book and [K51]. The first consequence is that given space-time sheet is characterized by two frequencies. A good guess is that the frequency difference associated with two space-time sheets connected by Josephson junctions corresponds directly to the voltage difference over Josephson junction: $\Delta\omega_1 = ZeV$.

11.2.5 Vacuum Quantum Numbers As Carriers Of Biological Information

The supra currents flowing in a closed loop of an organic polymer or of the brain nerve circuit depends linearly on the vacuum quantum numbers n_i, $i = 1, 2$ corresponding to the phase angles of the two complex CP_2 coordinates. The values of n_i for closed loops provide a way to store biological information and a model for the memory. The change of n_i in a closed loop is achieved by a phase slippage process creating a kink, that is a localized change of Φ or Ψ by an integer multiple of 4π or 2π respectively, propagating in the loop. Associated with the kink is a localized supra current depending linearly on the integer n_1. Kink like supra currents provide a a possible mechanism of the information processing at the bio-molecular level and at the level of the nerve cell, too. TGD based model of nerve pulse and EEG, to be described later, identifies nerve pulse as this kind of kink. The flux quanta are carriers of magnetic and Z^0 magnetic fields and these fields provide a candidate for memory storage and information processing mechanism.

11.2.6 Super-Symplectic Representations And Quantum Holograms

Peter Marcer [I54, I45] has strongly advocated the idea that quantum holograms are crucial for the information processing in bio-systems. TGD leads to a similar vision. An almost universal manner to satify field equations at the boundaries of space-time sheets is to assume that boundaries are light like 3-surfaces. For massless extremals (MEs) this condition can be always satisfied [K70] and in this case also the M^4_+ projections X^3 of MEs are light like. X^3 is completely analogous with the boundary of the future light cone and thus metrically two-dimensional. Therefore the cosmological super-conformal and super-symplectic symmetries generalize. Fractality, the classical non-determinism of Kähler action, and quantum holography suggest that the construction of the WCW geometry and quantum TGD can be in good approximation reduced to that in the sub-WCW s $CH(X^3)$ consisting of 3-surfaces in spaces $X^3 \times CP_2$ using super-conformal and super-symplectic symmetries.

The boundaries of MEs are in many respects like moments of big bang and by general coordinate invariance the states restricted to the boundaries contain all relevant information about the physical state in the "subcosmology" defined by 4-surfaces for which the M^4_+ projection is ME. This is nothing but quantum hologram property. The classical lighlike vacuum currents which are non-deterministic at given point of ME correspond to classical aspects of quantum communication and actually define dynamical hologram in the classical sense. super-symplectic transformations do not commute with Poincare transformations but the non-commutativity is expected to be small and only due to gravitational interactions. Thus gigantic multiplets of super-symplectic states with almost degenerate masses are predicted and are obviously ideal for representative purposes. Genuine quantum gravitational states in the space of 3-surfaces ("world of worlds") are in question and these states clearly represent higher abstraction level than ordinary physical states. Thus TGD seems to realize Marcer's vision in the sense that MEs would correspond to the highest and most abstract level of consciousness and intelligence in the self hierarchy. Genetic code would be analogous to read-only-memory burnt into the hardware and that most interesting and dominating information correspond to quantum holograms associated with MEs.

11.2.7 Many-Sheeted Space-Time Concept And Living Matter

The notion of many-sheeted space-time has several nontrivial implications. Many-sheeted space-time concept makes possible the transfer of particles between various space-time sheets. Since non-atomic space-time sheet are almost empty and couple weakly to atomic space-time sheets, this effect is expected to make possible effects like high T_c super-conductivity. The transfer of particles between two space-time sheets could along via possibly temporary join along boundaries bonds connecting the boundaries of the space-time sheets possibly belonging to different levels of the (self) hierarchy. The quantum dynamical counterpart of this process are supra-currents and Josephson currents running along join along boundaries bonds serving as Josephson junctions.

1. The first implication is the possibility of many-sheeted ionic flow equilibrium for a circuitry involving both atomic (non-super-conducting) and super-conducting space-time sheets (magnetic flux tubes). In ionic flow equilibrium extremely small densities of super-conducting ions and magnetic space-time sheets can be amplified to much larger ion densities at atomic space-time sheets. The magnetic induction interaction between magnetic fields of MEs and ions in magnetic flux tubes (analogous to interaction of the weak magnetic fields of brain with SQUIDs) allows MEs to control the magnetic quantum numbers characterizing supra-currents and thus also the ion densities at the atomic space-time sheets. Ohmic currents on atomic space-time sheets require weak but coherent em fields and this provides a reason why for why bio-matter must be liquid crystal and electret. The DC circuitry discovered already by Becker [J16] can be identified as the part of control circuitry associated with the atomic space-time sheets.

2. Josephson current serves effectively as a harmonic perturbation for the system formed by weakly coupled super conductors. If Josephson frequency corresponds to a difference for the energies associated with two states localized in either super conductor quantum jumps occurs leading to "wake-up" of sub-self occur. Also magnetic interaction with ME at magnetic transition frequency can induce magnetic transitions. Parallel supra currents running

in the weakly coupled super conductors could induce the resonant ion transfer. For instance, if the phases of the supra currents in the two super conductors are identical, constructive interference of Josephson currents associated with various junctions occurs. Josephson currents and resonant ion currents generated at critical Josephson frequencies might provide the royal road to the understanding of the quantum level coordination and control in the living systems [K73, K72].

3. Pairs of MEs make also possible "buy now, pay later" type energy production by generating negative energy space-time sheets. In the similar manner, effective generation of momentum becomes possible and the MEs with negative energy are optimal in this respect. Therefore the fundamental mechanism realizing "matter mind interaction" at the level of the space-time geometry could be in question. Bio-systems could also feed some fraction of their own gravitational flux to "nonstandard" space-time sheets and also channel part of the gravitational flux of Earth to "nonstandard" space-time sheets. This ability might make bio-systems antigravity machines. At negative energy space-time sheets classical fields could propagate backwards in time. Together with the vision about entire space-time surface as a community of mind like space-time sheets, one ends up with the idea that communication from geometric future to past is possible (and that we are just now discovering it!).

Obviously the notion of many-sheeted space-time would have fantastic explanatory power in biology. Thus it is especially gratifying that the strange findings challenging the association of ionic channels and pumps to cell membrane [I63] provide strong empirical support for the notion of many-sheeted space-time and for ionic super-conductivity at non-atomic space-time sheets. These findings will be discussed in [K22].

11.2.8 Self-Referentiality And Space-Time Topology

The notion of self-referentiality is one of the deepest and most fascinating notions of mathematics but for some reason it has not caught the full attention of physicists. I encountered the mystic variant of this notion during my "great experience" (the idea about living system as a computer sitting at its own terminal) and a more mathematical variant of the idea for a year or two later while reading the book "Gödel, Escher, Bach" of Douglas Hofstadter. It took however more than fifteen years before I managed to identify a possible concrete realization of the notion in TGD based physics.

Does physical system provide a representation for a theory about physical system?

MEs and magnetic mirrors play a key role in TGD based model of living matter. The connection with standard chemistry has been however lacking. It seems that some deep principle is needed to build this connection. The hints about the big principle come from the following observations related to the topological field quantization implying what might be called Bohr orbitology for the classical fields.

1. TGD predicts the existence of negative energy space-time sheets, in particular MEs: in Zero Energy Ontology (ZEO) this notion becomes rigorous and has quantum counterpart and can be understood in terms of a reversal of the arrow of geometric time. The prediction is based solely on the assumption that the space-time is representable as a 4-surface.

2. One could understand gravitational binding energy only if negative energy MEs represent this energy. This suggests that binding energy of a system has a very concrete representation as a negative energy MEs.

3. Quantum entanglement has as a geometric correlate join along boundaries bonds, in particular MEs and possibly also magnetic mirrors. Only the entanglement associated with the bound states is stable against the state preparation process leading to a maximally unentangled state in each quantum jump.

4. Classical superposition for em fields could mimic quantum superposition for states. The multiples of the fundamental frequency for ME could represent the BE condensate of bosons with energy defined by the fundamental frequency $f = c/L$.

5. The phase increments of the CP_2 coordinates around closed loops could represent phase increments of spinor fields and super-conducting order parameters around them as suggested in [K51].

6. flux tubes could represent even half-odd integer spin topologically. The flux tubes connecting 3-surface to a larger 3-surface get entangled in 2π rotation but in 4π rotation no entanglement results: this is due to the fact that the bonds provide a representation for the homotopy group of 3-dimensional rotation group. A good manner to visualize the situation is to think of a cube inside a larger cube with threads connecting the corresponding vertices of the cubes. An interesting question is whether also spin and statistics connection could be represented classically somehow.

These observations suggests a far-reaching generalization. Perhaps many-sheeted space-time allows the system to represent in its own structure the theory about itself. All theoretical concepts usually thought to have rather ethereal existence would have a concrete topological representation. These representations would exist already at the elementary particle level. Not only bio-molecules, but even hadrons, would be accompanied by a topological representation about their theory analogous to a written language. p-Adic-to-real transition would actualize this theory. Thus not only cognition but also symbolic representations of thoughts would be present in all length scales.

This idea of self-referentiality is actually an essential part of the basic philosophy of TGD. TGD inspired theory of consciousness implies that the Cartesian division to a world and theory about it is an illusion. Quantum histories, which are TGD counterparts for the solutions of field equations *are* the reality, there is no need to postulate any "real" reality behind them since conscious experience is associated between quantum jumps between quantum histories rather than the "real" reality. "Ontogeny recapitulates phylogeny" principle states that quantum histories have geometric and topological correlates at space-time level. This is just what the idea about topological representation of a theory about the system as a part of the system itself means. System could consist of a hierarchy of levels such that $N+1$: th level represents N: th level. Or perhaps more precisely, what results in the interaction of N: th level systems.

In atomic and molecular physics the basic implications would be following.

1. Atoms and bio-molecules would carry a representation about their own theory based on MEs. Since MEs carry light like four-momentum, they should appear as pairs of parallel MEs with opposite momenta and with frequency corresponding to one half of the binding energy: $f = E_B/2$. The frequencies associated with ME come as multiples of its fundamental frequency $f = c/L$, L the length of ME. This dictates to a high degree the lengths of the MEs associated with a given binding energy. The most natural length corresponds to the wavelength defined by one half of the binding energy. In the spirit of Bohr orbitology justified by quantum criticality allowing only preferred extremals of Kähler action with the property that there exists infinite number of deformations with a vanishing second variation, one can also require that ME pair has a classical energy equal to the binding energy: this requirement correlates the field strength and the thickness of the negative energy MEs.

   The natural expectation is that the number of critical deformations is infinite and corresponds to conformal symmetries naturally assignable to criticality. The number n of conformal equivalence classes of the deformations can be finite and n would naturally relate to the hierarchy of Planck constants $h_{eff} = n \times h$ (see **Fig.** `http://tgdtheory.fi/appfigures/planckhierarchy.jpg` or **Fig. ??** in the appendix of this book).

2. Atomic binding energies would correspond to MEs with wavelengths in UV region. The binding energies of typical covalent bonds would give rise to MEs with lengths in wavelength region which corresponds to UV and visible light. The binding energies of hydrogen bonds in turn would give rise to MEs with lengths which correspond to wavelengths in the near infrared, cell size would be the typical length scale.

3. In the case of a potential well, such as the one associated with a harmonic oscillator or constant magnetic field, a natural representation would be in terms of positive energy ME allowing various harmonics. Vibrational and rotational frequencies would correspond to infrared and microwave region and magnetic energies to ELF region. The idea that these

frequencies correspond to high level representations for the system is of course already now a basic element of TGD inspired theory of consciousness and conforms fully with the idea about topological self reference.

Possible biological implications of topological self reference

The notion of topological self-referentiality, if correct, means the possibility to combine enormous amount of knowledge from biochemistry to build a concrete view about em bodies of molecules and about how living matter represents itself in its own structure. One could also try to identify the chemical counterparts for the special frequencies predicted by the p-adic length scale hypothesis. One might even hope that one could at some level understand how such very high level phenomena like written language emerge from the topological self-referentiality. What is so interesting is that the hypothesis connects various length scales. For instance, the binding energies of atoms with nuclear charges $Z \sim 10$ are in keV range and correspond to MEs with size of order nanometer. Perhaps even the structure of condensed matter is partly coded into the representation of the binding energies of atoms.

Some examples of the possible consequences in biological length scales deserve to be mentioned.

1. The many-sheeted structure associated with a molecule would provide a representation for the molecule identifiable as its electromagnetic signature introduced in the theories of homeopathy and water memory [K44]. And not only this: this structure would also serve as a 4-D dynamical hologram serving as a photograph-like template for the self-organization of matter around the molecule. This would mean effective reductionism, but obviously only effective.

2. Genetic code would be a highly developed form of this representation. It would involve the negative energy MEs associated with various atomic and molecular binding energies. Especially important negative energy MEs would be in the visible region and associated with the covalent bonds and in the near infrared associated with the hydrogen bonds connecting DNA nucleotides together. Also the MEs associated with rotational and vibrational degrees of freedom are expected to be very important and for them liquid crystal blocks of water could serve as mimickers and amplifiers. The transparency of water to visible frequencies (covalent bonds have energies 4.7 eV in UV region) means that water is an ideal medium in the visible region for communications by MEs since coherent visible light can propagate long distances with attenuation caused only by the absorption by bio-molecules.

This picture gives a justification for the suggestion of Peter Gariaev that DNA is accompanied by laser mirror pairs [I45]. The negative energy ME pairs associated with various binding energies would correspond to the laser mirror pairs. This picture differs slightly from the earlier proposal for the realization of genetic code involving orthogonal pairs of MEs associated with each nucleotide giving rise to 4 different pairs of polarizations and suggests a simpler realization in which the four polarization pairs associated with a pair of parallel MEs would realize the genetic code in a given length scale.

Topological self-referentiality allows also to understand what happens in overunity energy production and these insights might be also crucial for the understanding of how life has evolved as a parallel development of macroscopic quantum bound states and the ability to metabolize. The components of the system can bind mutually or with the environment and negative energy space-time sheets represent binding energy. Bound state energy is liberated as a usable energy. The resulting bound states have entanglement irreducible under state function preparation process: this makes possible fusion of sub-selves to larger sub-selves. The bound states correspond to space-time sheets having typical sizes given by the p-adic length scale hypothesis and the process means basically space-time engineering. The typical wavelength of the radiation emitted in the process gives estimate for the electromagnetic or gravitational size of the bound state. In ELF frequency range the electromagnetic size is of order Earth size. Electrolytic processes are especially interesting from the point of view of over unity energy production.

For instance, the production of hydrogen molecules in the electrolysis of water might be accompanied by the formation of large bound states of water molecules and the liberation of the binding energy as a usable energy. The signature for the process is simple: the energy liberated is larger than the energy deduced from the binding energies of water and hydrogen molecules. Rather interestingly, the hydrogen bond energy deduced from the evaporation energy per water molecule is .485 eV and is very near to the photon energy $E(167) = .4844$ eV corresponding to p-adically scaled up electronic Compton length $L_e(167) = 256L_e(151)$ for $L_e(151) = 10$ nm: $k = 167$ is one of the four subsequent scales $L_e(k)$, $k = 151, 157, 163, 167$, which correspond to Gaussian Mersennes. Perhaps cold fusion involves both the nuclear fusion by Trojan horse mechanism and the formation of large scale bound states. Biology provides an important area of applications and the model of bio-photons developed in [K44] leads to a concrete model for the generation of pairs of positive and negative energy MEs at DNA level. Bio-molecules and cells are are indeed bound states of macroscopic size.

The first form of life evolved under conditions in which electrolytic processes occurred: perhaps bound state formation led to the generation of bio-molecules and cells. What is nice that the development of long range order (negative energy MEs) would have been automatically accompanied by the development of metabolism (positive energy MEs!). Sol-gel transition crucial for the cellular locomotion is a particular example of this process. Thus a natural path to follow in the attempts to build new energy technologies is to try to mimic what living nature has already achieved. This kind of energy production would be also wasteless and support evolution. Quantum spin glass analogy means that Kähler action has an enormous almost ground state degeneracy and only classical gravitational energy differentiates between different ground states. Thus the classical gravitational binding and also the generation of coherent gravitons by MEs might have a role to play in the quantum physics of living matter. A rough order of magnitude estimate for the gravitational binding energy for a blob of water having size $L_e(k)$ is

$$E_{gr} \sim \frac{GM^2}{L_e(k)} = G\rho^2 L_e(k)^5 \sim \frac{Gm_p^2}{L_e(137)} \frac{L_e(k)}{L_e(137)^5} \simeq 2^{-127} 2^{5/2(k-137)} \frac{1}{L_e(137)} \quad .$$

Gravitational binding energy is larger than the p-adic energy $\pi/L_e(k)$ for $L_(k = 179) \simeq .169$ mm. In the range $L_e(163) = 640$ nm and $L_e(167) = 2.56$ μm gravitational binding frequency varies between 1 Hz and 1 kHz, that is over EEG range up to the maximal frequency of nerve pulses. For $k = 157$ and $k = 151$ the gravitational binding frequency corresponds to a time scale of 9 hours and 100 years respectively so that the time scales relevant for life are spanned by the Gaussian Mersennes. Perhaps gravitonic MEs carrying vanishing em fields accompany the basic building blocks of the cell. Neither the connection with EEG is excluded.

11.3 Realization Of The Lower Levels Of Biological Self Hierarchy

Am important question concerns about actual biological realization of the self hierarchy predicted to begin already at elementary particle level and continuing indefinitely. TGD indeed leads to rather concrete ideas about how this hierarchy is possibly realized. In the following the lowest levels of the hierarchy are discussed.

11.3.1 General Ideas About Biological Self Hierarchy

Neurons are only one level of selves in the biological self hierarchy starting from the level of body and sensory organs (or possibly from much higher level) and ending up to the level of 64 basic DNA triplets via neurons and micro-tubuli and all between (or probably continuing even further downwards as suggested by the estimate for the duration of self as p-adic time scale associated with the system).

Buddhists classify fundamental experiences to 64 basic types in I Chin. One can (with tongue slightly in cheek) wonder whether they have achieved in meditation the level of DNA selves and recognized its presence clearly? In [K43] a very simple model of abstraction process reproducing the basic numbers of genetic code is discussed and in this framework DNA: s might provide a physical realization for selves representing basic mutually consistent statements of simple formal system.

The model for the abstraction process also predicts higher levels of the hierarchy and the identification of the next level as the "memetic code" leads to correct predictions for the duration of psychological moment and for the time scale of nerve pulse duration. It turns out that these levels could involve also electromagnetic selves and bodies with size of entire Earth: the conclusion follows using only Uncertainty Principle and topological field quantization.

11.3.2 Criteria For Being Biologically Significant Self

The biologically relevant selves might be distinguished as selves able to stay awake for sufficiently many quantum jumps. Possible additional criteria are following.

1. Self corresponds geometrically to a system with a well defined inside and outside. In standard physics context this requirement looks too strong. For instance, it is questionable whether DNA satisfies this requirement in standard physics framework. In TGD framework inside-outside decomposition is satisfied if system corresponds to a separate space-time sheet. Presumably DNA and proteins satisfy this criterion.

2. The effect of anesthetics on self candidate must affect also our consciousness. In TGD framework loss of sub-selves at any level affects the experience at the higher levels so that this criterion is sensible.

3. The behavior of self candidates should show responsiveness and adaptivity. Selves should demonstrate the ability to control their own structure or the structure or behavior of the structure to which they belong. These abilities would follow from the ability of self to quantum self-organize. For instance, in case of proteins the allowed protein foldings could be regarded as fixed states of self-organization by quantum jumps.

4. The exponent of the Kähler action provides measure for the cognitive level of the subsystem measured as the number of degenerate space-time surfaces associated with given 3-surface. Thus the presence of strong Kähler electric fields fields is a good signature for the presence of cognition. Polar molecules (say proteins) are thus good candidates for systems containing selves.

5. Self candidates should be able to communicate. One possible means of communication is proton conduction in ordered water associated with the structure. Second means of communication are dipole oscillations: this requires that structures in question are polar. Wormhole BE condensate and coherent photons provide TGD based means of communication. Also electrons "dropped" on larger space-time sheets provide make possible this kind of communication.

6. There exist irreducible selves containing no sub-selves. Irreducible selves are thus "elementary particles" of consciousness. This slightly "romantic" criterion is motivated more by my particle physicist background and should be only taken as an attractive candidate for a rule of game.

11.3.3 Possible Interpretation For The System Formed By DNA And Proteins

In [K26] it was proposed that DNA and proteins could form a physical representation for so called formal systems [D12] formalizing arithmetic systems to a set of symbols and rules for manipulating them. DNA sequences represent possible special cases of theorems represented by amino acid sequences and genetic code is mapping determined which are the special cases corresponding to given theorem. The larger structure formed from proteins correspond to statements about statements. This suggests that proteins and higher level structures formed from them forming self hierarchy give meaning to the theorems represented by amino-acid sequences.

The modelling of DNA and protein interactions is based on chemical kinematics which is basically a statistical model for the time development by quantum jumps occurring at the level of individual chemical compounds.

This requires that DNA and proteins participating the chemical reaction form entangled subsystems of some self and that quantum jumps leads to states in which reaction products become are unentangled subsystems, possibly selves which stay awake for some time. This argument only requires that some larger system containing DNA and proteins is in self state. This system could be some cell organelle, nucleus for DNA replication to mRNA and ribosome for the translation of mRNA to proteins. In this picture the magical looking processes of biochemistry (replication of DNA, translation of DNA sequences to protein molecules) could be understood as fixed points of quantum self-organization resulting from a sequence of quantum jumps. For a wake-up time of order 10^{-10} seconds this would mean 10^{30} quantum jumps during single wave-up period of self. Therefore the precise determinism of DNA replication and translation could be perhaps understood as processes completely analogous to the formation of convective pattern in Benard flow. Final state would only depend on the macroscopic parameters the self containing the reactants (pH, temperature, electric fields).

This picture allows a realization of self hierarchy in which the fraction of time (quantum jumps) spent in self state increases with the size of the self. Natural guess is that this time scales as the size of the system. Wake-up time of 10^{-10} second in protein length scale would give time of order second in the length scale of meter which look rather sensible result. In the following a first guess for self hierarchy based on some general criteria is proposed.

11.3.4 Proteins As Selves And Protein Folding

Proteins are good candidates for building blocks of self-hierarchy for several reasons.

1. Proteins are known to react sensitively to what happens in the surrounding world by changing their conformation.

2. Individual proteins are characterized by a huge number of enfoldings and one of the mysteries of biophysics is to understand what determines the few allowed configurations that are actually realized (self-organization by quantum jumps and spin glass analogy might help to solve protein enfolding problem as suggested in [K87].

3. Proteins are polar molecules and form electrets. This is in accordance with the fact that electric field serve as a measure for cognitive resources. Already Fröhlich suggested that electret property is crucial for life. Proteins contain both hydrophilic polar parts and hydrophobic residues. The enfolding of proteins creates “dry” pockets in which hydrophobic residues of the proteins point inward so that one can speak of inside-outside distinction. It is not however clear whether one cannot regard protein pockets as selves having sufficiently long lifetime. Protein folding seems to however require that protein cannot be irreducible self but decomposes in quantum jumps to subsystem and its complement. How long times subsystems created in this manner can spend in self state is an open question.

4. There are speculations that these pockets could form the “brain” of protein. The states of this tiny brain would corresponds to the conformations of hydrophobic residues inside pocket. The motivation is that anaesthetics seem to act on the electrons associated with the pockets and reduce their motility.

   In TGD framework one could understand the ability of protein to control its conformation as resulting from the interaction between the electrons in the pockets with the wormhole BE condensate associated with the boundaries of the protein. In quantum jumps electrons could entangled with the conformations of proteins and quantum jump would select one conformation. The loss of electron mobility by interaction with anestetics leads to the loss of protein self or at least the ability to protein to control its motions by quantum jumps. It seems however unnecessary to assume that electron or hydrophobic pockets behaves as a self.

5. Proteins are typically surrounded by ordered water and proton conduction makes possible communication. The dipole oscillations associated with the polar bonds of proteins provide a second communication mechanism. Wormhole BE condensate and coherent photons provide additional purely TGD based communication mechanisms. Also electrons dropped to non-atomic space-time sheet could provide a new conduction mechanism.

Protein folding is one of the mysteries of biology and provides direct justification for the hypothesis that proteins has self. The duration of the self of average protein having length of order 10^{-7} meters is about 10^{-15} seconds: this time scale corresponds to the wavelength of visible light. The assumption that protein can be in self state resolves the mystery of protein folding [K87]. The self-organization occurring inside protein self leads unavoidably to a bottom of some deep valley in the energy landscape of the protein representing the values of Kähler function for various protein conformations. Dissipation associated with self-organization by quantum jumps selects the final pattern of self-organization determined by external parameters like pH and temperature and with very slight dependence on initial conformation.

11.3.5 Larger Selves Formed By Proteins

The larger structures formed by proteins give rise to the next level of the self hierarchy. The basic hydrophobic-hydrophilic splitting of the protein personality implies that proteins dissolved in water form very rich structures. Typically bi-layered structures, micelles, for which hydrophobic residues point inwards, are formed. Hollow cylinders, spheres and disks are possible. Micelles self-organize further to form liquid crystal phases. The end result of self-assembly depends on the pH, ionic concentrations and temperature of as well as electric fields in the surrounding water. Rather general belief is that the dipole oscillations of proteins could be the Bose-Eistein condensate relevant for bio-consciousness. TGD framework suggest that the Bose-Einstein condensate of charged wormholes located on boundaries of tubulin dimers is one relevant BE condensate: the charge density of the wormholes is in fact equal to the normal component of electric field on boundary. The completely new element is the presence of phase of the wormhole order parameter mathematically analogous to order parameter of super-conductor. One can say that wormholes are the square root of the dipole condensate of Fröchlich.

Micro-tubuli

Protein molecules arrange into several, typically linear structures. The cytoskeleton is formed by micro-tubuli [J28, J70]. They consist of hollow cylinders formed as a lattice like structure of tubulin dimers. Tubulin dimer consists of two tubulin isomers, α- and β-tubulin. Second tubulin isomer contains attached Ca^{++} ion and second isomer contains two electrons, the other one being in the region intermediate to the isomers. Therefore tubulins are polarized. The region, where the tubulins of individual tubulin dimer join together, contains an electron. Tubuline dimers have at least two basic conformations and give rise to two different polarization states. Quantum jumps of the electron in the hydrophobic pocket are believed to induce jumps between the two conformations. Anesthetics are known induce aneasthesia by affecting the mobility of these electrons. The relevant interaction is presumably van-der-Waals interaction since even noble gases are known to act as anesthetics [J70].

An important question is whether the tubulin isomers are sub-selves of micro-tubule or not. The crucial question is whether tubulin isomers have mutual flux tubes. Join along boundaries bonds/flux tubes carry magnetic or electric fluxes and this would require magnetic or electric polarization of tubulins joined by the join along boundaries bond. Tubulins have only van der-Waals type interactions induced by the induced dipole-moments. This suggests that join along boundaries bonds are not present. The important conclusion is that tubulins are excellent candidates for selves and the mental life of micro-tubule can be very obviously very rich. The two conformations corresponding to two different polarization states of the tubulin would give a rough characterization for the mental state of single tubulin.

The lattice formed by polarized tubulins dimers can be regarded as a spin lattice like structure. The first phase corresponds to randomly oriented dipoles. This phase is ideal for communication since arbitrary message can be conveyed. Second case corresponds to spin glass like phase with groups of neighboring dipoles are in same orientation. This phase is ideal for computational activities since the configurations are temporally stable and memory storage becomes possible. The third case correspond to ferro-electret phase with all dipoles having same orientation.

If tubulin isomers are selves, they are rather simple selves having perhaps only two basic mental states corresponding to two different tubulin conformations. The mental state of micro-tubule self is "sum" of the tubulin selves and experienced by the micro-tubule as separate mental images. This if entanglement between tubulins is absent. In this manner the mental state of the micro-tubule could perhaps be interpreted as representing a binary sequence. Even the interpretation as a conscious computer could be considered. The mental states of the micro-tubule self would correspond to time developments of the tubulin conformations starting from the last moment of wake-up. Conformational waves propagating along micro-tubule, suggested also in [J28] to correspond to fundamental mental images, would give rise to very rich repertoire of micro-tubular experiences. Thus anesthetics reducing the mobility of electrons in hydrophobic pockets should have a dramatic effect also on "our" consciousness.

Cell membranes

Cell membranes are basic example of a structure formed by two lipid layers such that the hydrophobic residues point inwards. The region between the lipid layers could perhaps be regarded as forming "cell membrane self". The hydrophobic tails of lipids point inwards. Unless the lipids contain hydrophobic pockets, there are no candidates for sufficiently long lived lower-level selves. Thus cell membranes could perhaps in good approximation be regarded "irreducible selves" having no mental images.

Cell is full of endoplasma membranes and contains also cell organelles like nucleus surrounded by similar membranes. All these membranes are good candidates for material counterparts of selves if the proposed criteria are accepted. One possibly relevant macroscopic quantum phase is now the BE condensate of wormholes [K121].

Larger structures

1. Protein collagen is the main component of the connective tissue in living systems. According to observations of Mae-Wan Ho [I76], collagen forms liquid crystalline mesophases extending through the entire body. This encourages the conjecture that collagen fibres, which could be regarded as a scaled up version of cytoskeleton formed by micro-tubuli, could form one level in the self hierarchy. Mae-Wan Ho has indeed suggested that this structure is the seat of body-consciousness [I76].

2. Entire cells, having clear inside-outside separation, are good candidates for selves and the superpositions of mental images of micro-tubuli would be part of the content of conscious experience of "cell self". The binary structure of micro-tubuli indeed makes possible very large number of different mental states even in the case that the contents of the cellular conscious experience reduces to the conformational dynamics of tubulins.

3. The two cell layers in epithelial sheets form a structure, which is much like a scaled up version of the cell membrane. Bio-systems are full of these structures: both skin, organs and the nuclei of brain are surrounded by epithelial sheets. In TGD based model for bio-consciousness "our" consciousness is assigned with the structures formed by epithelial sheets.

4. Brain contains also larger bi-layered structures, which seem to correspond to twin integers k and $k+2$ such that $p \simeq 2^k$, k power of prime is p-adic prime. These structures could give rise to even higher levels of consciousness. One possibility is that the hierarchy sensory-emotional-cognitive corresponds to p-adic length scale hierarchy, perhaps $k = 169, 173, 179$. Also the level $k = 181$ could be present and correspond to highest levels cognition. Cell layers forming ocular dominance columns correspond to $k = 179$ whereas $k = 181$ corresponds the combination of visual fields to stereo vision. This suggests that $k = 181$ combines the experiences of left and half brain to single experience.

11.3.6 Identifying Our Sensory Sub-Selves In P-Adic Length Scale Hierarchy

The synchronous firing of neurons would mean the "waking up" of quantum critical neuronal selves in a cascade like manner (think of fox perceived by a crowd of hens sleeping initially!). The receival of a nerve pulse would wake up neuron. Perhaps neurons inside synchronously firing neuron groups of both hemispheres have small real entanglement slightly above the critical value for wake-up so that small perturbation is needed for wake-up. In this case neuronal self creation would not involve any quantum jump.

The nature of cognitive act depends on the type of the quantum entanglement involved as well as on the nature of wake-up process. The richness of structure associated with dark matter hierarchy implies that very many combinations are possible for cognitive cascades possessing several levels and at this stage one can only speculate. A rather speculative TGD based model for thoughts is based on "cognitive neutrino pairs" consisting of dark neutrinos as giving realization for Boolean algebra. The density of dark neutrinos is predicted to be very low in p-adic length scales much larger than $L_e(169) \simeq 5\ \mu$m (two times cell size roughly). The defects of dark neutrino super conductor could define representations of thoughts and in the simplest model the macroscopic quantum phases formed by Z^0 magnetized antineutrons at the cell membrane space-time sheet give rise to symbolic representations of thoughts.

If the levels of self hierarchy correspond to p-adic space-time sheets and dark neutrinos are present at all levels, thoughts cannot involve too many hierarchy levels. In the model of cell membranes as defects of dark neutrino super conductor, the relevant p-adic length scales correspond to $k = 169$ and $k = 151$. If dark neutrino super conductor can however form defects also at levels $k = 167, 163, 157$, then hierarchies with four levels are possible (sentences, words, syllables, phonemes?).

Direct support for the idea that the components of our conscious experience correspond to sub-selves comes from the phenomenon of after mental images. For instance, by looking at bright light source and closing eyes, one can experience periodically emerging after images changing their color. Phenomenon is actually much more general: all our mental images tend to occur periodically. A natural explanation is in terms of a periodic wake-up of the sub-selves representing these mental images. Even we are periodically occurring mental images of some high level self if the hierarchy of selves exists: there would be no deep difference between thinker and thought!

One could wonder how many cognitive sub-selves (mental images) we typically have. 7 ± 2 rule of psychology states that we can typically classify things into this number of different categories unless we use auxiliary tools. For instance, the number of digits in phone number is typically 7 for this reason. During intense concentration the number of categories is smaller and can reduce to only one. This would suggest that the number of cognitive sub-selves is typically 7 ± 2: of course, also other kinds of selves, such as bodily self, can exist simultaneously.

Good candidates for *our* sub-selves are structures bounded by epithelial sheets bounding various structures. Our body is full of these structures: skin, various organs and various brain nuclei, especially hypothalamus, hippocampus and reticular formation [J70] are examples of these structures. The seats of the primary sensory experiences should contain primary sensory organs. Hippocampus is crucial for laying down of the long term memories and this suggests that hippocampus can quantum entangle with higher level selves having long range memories as subjective memories. Limbic brain and hypothalamus are often regarded as the seat of emotions and the simplest hypothesis is that limbic brain is the seat of emotional consciousness which involves the comparison of the geometric memories with subjective memories. The damage of the reticular formation, which is the oldest and the most primitive part of the brain, implies unconscious state (at least using the generally accepted criteria for consciousness). Since reticular formation is not active during dreams, also the other parts of brain must have the ability to perform quantum jumps so that the sometimes heard claim that reticular formation is the seat of consciousness is incorrect. Various sensory homunculi in brain are good candidates for sub-selves performing higher level processing of the sensory information (pattern recognition, novelty detection, ...).

An interesting question is what subconscious activity as opposed to unconscious activity might mean: one might think that this kind of activity is conscious activity of some self at the same level of self hierarchy as "our self". Perhaps Zombi within us type phenomena such as blind sight correspond to activities of this kind of parallel self perhaps identifiable as body with sensory organs acting as primary sensory experiencers. Could drives correspond to the desires of limbic brain or higher level selves? Could association cortex or even society correspond to the desires of "superego" ? Could the splitting of the personality correspond to the presence of a too large number of parallel "our-selves" and having conflicting desires and plans? Or is poor communication between "our-selves" the problem. It has indeed been found that the hemispheres of the split brain subjects are separately conscious [J70]. The "collective unconscious" of Jung, on the contrary, might correspond to larger self, say, the whole society or even bio-system.

11.3.7 Hardware For Body Consciousness

The great challenge is to identify the hardware for the self hierarchy. The ideas of Mae-Wan Ho and her colleagues [I76, I77, I67, I68] seem to be on right track in this respect. Mae-Wan Ho has suggested that collagen network of body gives rise to body-consciousness understood to be something different from brain consciousness under usual conditions. This hypothesis indeed seems natural also from TGD point of view.

Liquid crystals

Liquid crystals (for excellent introduction see [D4] containing online text book about liquid crystals) can be regarded as mesophases: phases which are intermediate between solid crystal phase and liquid phase. Large class of crystals indeed appears in narrow temperature range between crystallization and melting.

The molecules able to form liquid crystals must be non-symmetric under rotations. Typically rod like or disc like molecules are in question. The detailed structure of the molecule does not matter: typically only length-to-thickness ratio is what characterizes liquid crystals. Liquid crystal molecules contain also rigid polarizable part. Permanent dipole moment does not seem to be essential for liquid crystallinity.

Liquid crystals allow two basic phases. In nematic phases there is long range orientational order but translational order is lost. In smectic phases translational order is present in single direction and liquid crystal behaves like liquid orthogonal directions and has layer-like structure. Each layer behaves like two dimensional liquid. Molecules in each layer have definite average direction which can vary from layer to layer. If liquid molecules are chiral, the orientation of the molecules in layers can rotate helically.

The liquid crystals formed by collagen forms are lyotropic liquid crystals. Lyotropic liquid crystals are formed by amphiphilic molecules, surfactants, in polar solvent, say water. Amphiphilic molecules have hydrophilic and hydrophobic parts. Above critical concentration surfactant molecules form micelles, which are hollow spherical, cylindrical or disk like structures such that the hydrophobic residues point in interior and hydrophilic residues form hydrogen bonds with surrounding water. The liquid crystals in question can be electrets. In smectic phase, the direction of spontaneously generated electric field is parallel to the layer formed by micelles. Micelles themselves can have spontaneous polarization. Cell membrane is biologically important example of a polarized spherical micelle formed by lipids of cell membrane in which hydrophobic lipid tails point inwards.

Micelles, rather than molecules are building blocks of nematic and smectic phases which are formed when concentration is further increased. The formation of micelles and nematic and smectic phases occurs via self-assembly and could be regarded in TGD framework as quantum self-organization process. The result of self-assembly is sensitive to pH and ionic concentrations of water, to temperature and hydration of water and to external electric fields.

Both micro-tubuli and collagen can be regarded as examples of liquid crystals. There are many kinds of collagens. All share a general repeating sequence of the tri-peptide (X-Y-glycine), where X and Y are usually proline or hydroxyproline. They also have in common a molecular structure in which three polypeptide chains are wound around one another in a triple helix [I77]. In case of collagen liquid crystal micelles are long cylindrical structures, fibrils and these in turn organized to fibers with thickness of 1-20 micrometers [I77]. Cells can be regarded as micelles and therefore the layered structures formed by cells could also be regarded as liquid crystals. Epithelial sheets could perhaps be regarded as higher level micelle.

Living organisms as liquid crystals?

The book “The Rainbow and the Worm” of Mae-Wan Ho [I76] represents empirical support for the concept of body consciousness. The lecture talk of Mae-Wan Ho [I77] gives brief summary and references to the work by her and her colleagues. There are very simple observations supporting the notion of body consciousness.

1. Oscillations in olfactory bulb and in brain are in in phase with the movement of lungs. Also the coordinated movement of four limbs in locomotion is accompanied by patterns of activity

in motor centres of brain which are in phase with locomotion. It is very difficult to understand how this could be possible if brain would be only a central unit organizing these movements. Lags of order one second would be expected. Rather, it seems that brain and body work as a coherent unit.

2. Hydra and sea anemone, which have no nervous system, contract very rapidly when one of tentacles is touched. This suggests that consciousness is not a property of only nervous system but present already at the cell and body level.

Mae-Wan Ho [I76, I77] suggests the identification of the hardware of body consciousness as collagenous liquid crystalline mesophase [I68] associated with the connective tissue present everywhere in the body. Collagen is the most common protein of body and gives rise to a mechano-electrical network making possible for the parts of body to act as a coherent whole.

1. Collagen is a good conductor of electricity. The conduction mechanism is proton jump conduction in the ordered water associated with the collagen. Proton jump conduction is much faster than nerve conduction. The conductivity increases by addition of water when the amount of absorbed water is 10-30 per cent of total weight. The maximum increase occurs at body temperature.

2. Collagen forms mechanical network having connection with intracellular matrices through proteins located on cell membranes. Collagenous network, being liquid crystal, is characterized by the local orientation of the fibrous structures. For instance, in skin the alignment is due to stresses and strains during growth. Similar oriented fibrous structures are present in bones and cartilages. The hydrogen bonded water associated with the collagenous fibres makes this network also a electrical network having connections with the intracellular structures. These properties make collagen network an electro-mechanical network making possible intercommunication and responsiveness.

3. Proteins in liquid crystals have coherent motions constrained strongly by the fibrillar structure. These mechanical motions involve vibrational deformations of protein bonds accompanied by polarization waves coupling to proton conduction. Very weak, mechanical, electrical and thermal signals are amplified and propagate as modulation of proton currents or coherent polarization waves. Metabolic pumping of energy is probably involved.

4. Acupuncture system is known to have rather interesting manifestations. For instance, the stimulation of an acupoint in little toe leads to a similar activity in visual cortex as flash of light [J21]. This cannot be explained in terms of standard neuroscience. Stimulation of acupuncture points can produced local anesthesia. Thus acupuncture points and meridians might be closely related to body-consciousness.

5. Becker discovered the so-called body DC electric fields [J16, J27] are of central importance for consciousness. Becker found that general anesthetics attenuate the DC field completely. Sleep state can be induced by manipulating these fields using external currents. Becker also observed that during a perceptive event local changes in body the DC field can be measured half as second before the arrival of the sensory signals in the brain. There is also evidence that anesthetics act by replacing and releasing bound water from proteins and membrane interfaces. It is known that patients under general anaesthesia can regain brain consciousness with accompanying experience of pain. On the other hand, local anesthesia by acupuncture has been applied to patients who are fully awake. Acupuncture points are known to exhibit low electrical resistances as compared to the surrounding skin and could be juncture points of this network.

   Mae-Wan Ho suggests that collagen network, body DC fields and acupuncture system are closely related. Conduction channels could be associated with the fibrous structures formed by collagen, most probably the bound water in collagen fibres would serve as electric conductor.

6. One of the basic mysteries of living systems is their ability to move coherently. Some miraculous mechanism making it possible to transform energy to coherent energy must be in use.

Otherwise the energy of metabolism would go to an disordered molecular motion and no macroscopic motion would be possible. Mae-Wan Ho also introduces the concept of coherent energy [I77], which is the counterpart of "qi" in ancient Chinese medicine. For instance, coherent energy could correspond to collective motion in which momenta of particles are in same direction. Bio-systems seem to have ability to store fraction of incoming energy flux as coherent energy. This is not in contradiction with the second law of thermodynamics if the necessary dissipation occurs outside the bio-system or in some part of special part it. What is difficult to understand in the framework of standard physics is how bio-systems could so cleverly circumvent second law of thermodynamics.

TGD based view about living systems as liquid crystals

Protein molecules able to form micelles and crystals seem to be ideal candidate for realizing self hierarchy physically.

1. Liquid crystals are in a well defined sense critical phenomenon. This is in concordance with the idea that bio-systems are quantum critical systems.

2. The independence of the properties of the liquid crystal on the detailed shape of molecule is in accordance with idea that liquid crystal phase must be assigned to some non-atomic space-time sheet at which molecule is represented by the distribution of the wormhole contacts on the boundary of the molecule. Lyotropic liquid crystals are simple in the sense that micelles are basic building blocks with very simple geometry. Note that collagen proteins, micelles formed by them and liquid crystals formed in turn by them form naturally a hierarchy, perhaps identifiable as self hierarchy.

3. Liquid crystal assembly are sensitive to external electric fields, pH and ionic strengths. Also this supports the picture based on interaction between charged wormholes a proper description for the interaction between basic units of liquid crystal. For pure water pH determines the density of the water molecules on the boundary of 3-surface containing water molecules ($pH = -log(H_+), pH + POH = 14$). This is in accordance with the interaction between proteins occurs indeed via the classical em fields associated with wormholes on the boundaries of proteins. Note that as proteins contain peptide bonds which are polar. These polar bonds could involve wormhole contacts making possible amplification of the electric field in the direction of bond. There must be a compensating electric field on the larger space-time sheet.

4. Lyotropic liquid crystals seem to be ideal as far as consciousness is considered.

   (a) The hierarchy formed by proteins, micelles formed by them, and liquid crystals formed in turn by the micelles, could be interpreted as par of the physical realization of self hierarchy. At the lowest level are hydrophobic pockets of proteins and at the highest level collagen structures and organs formed by the cell layers.

   (b) If one believes on the hypothesis that Kähler action provides an entropy type measure for cognitive resources, then the presence of electric fields and spontaneous polarization can be regarded as advantageous from the point of view of cognitive consciousness.

1. First vision about liquid crystals and consciousness

The proposals of Mae-Wan Ho are restricted to the framework of the classical physics and, even if of crucial importance, might not be enough to allow understanding of body as a macroscopic quantum system. TGD suggest a more radical views about the role of collagen network, DC fields and acupuncture system in making possible body consciousness. The first vision developed for few years ago (this particular "now" corresponds to year 2001) is following.

1. In TGD one can understand the coherence of bio-system in terms of the classical coherence resulting from connectedness of appropriate 3-surfaces made possible by join along boundaries contacts ("massless extremals") in turn implying quantum coherence. Classical connectedness is quantum correlate for quantum coherence making possible subsystems to quantum

entangle. Note that the concept of 3-surface is something totally new from point of view of standard physics were the modelling of the macroscopic structures is based on completely ad hoc assumption about their existence.

2. Liquid crystals look in short length scales like ordinary crystals behaving like single macroscopic unit. This behavior is something totally different of that of ordinary dissipating systems. A possible interpretation is that these units are irreducible selves and, being in a state of whole-body consciousness, do not dissipate in the usual manner. Thus body would consists of parts spending considerable fraction of time in a state of whole-body consciousness. If these regions belong to same level of self-hierarchy, they do not know about each other. "Brain self" knows nothing about "heart self".

3. The observations of Becker [J16] about the role of the electric fields in consciousness fit nicely with the TGD based hypothesis that the negative of Kähler function measures gives entropy type measure for the cognitive resources of the 3-surface. Exponent of Kahler action gives essentially the number of absolute minima of Kähler action going through given 3-surface. The generation of Kähler electric fields is a basic manner to increase cognitive resources. In light of this one can understand why cell membranes carry huge electric fields and why body DC fields, perhaps associated with the epithelial sheets consisting of two cell layers, are fundamental for our consciousness.

4. p-Adic fractality and many-sheeted space-time concept lead to the idea that epithelial sheets consisting of two cell layers could give rise to a scaled up version of nervous system. The basic phenomena would be periodic collective oscillations and propagating solitons in the Josephson junctions formed by the cell layers of the epithelial sheets. The electro-chemical shadows of these phenomena could be different from those in case of ordinary nerve pulse and EEG. Liquid crystals [D4] are typically electrets consisting of layered structures having electric fields in the transversal direction of the symmetry axis. DC fields could correspond to longitudinal electric fields associated with collagenous fibres and in direction of the fibres.

5. TGD suggests new physics mechanism realizing the notion of coherent energy purely classically. An interesting possibility is that the generation of "massless extremals" with net momentum basically generates the volitional macroscopic coherent motion in living systems. The properties of the collagen network might make it possible to "buy now and pay later" and also provide guarantee for the payment. Payment would mean that the negative energy massless extremal is absorbed by living system itself or surrounding world. Most naturally this absorption occurs when the motion of part of organism ceases. At this moment organism must be able pay back the energy gain. Thus metabolism would be needed to stop the motion rather than to initiate it! The only sensible interpretation is that stopping occurs automatically and is forced by the classical field equations.

An interesting question is whether non-volitional phenomena like heart beat involve emission of the negative energy massless extremals. The emission could indeed be purely classical process. Of course, heartbeat could be non-volitional only from the point of view point of "brain self". There could be "heart self" making decision about each heart beat!

2. Second vision about liquid crystals and consciousness

The first reason why for liquid crystals involves rather general arguments. The notion of many-sheeted ionic flow equilibrium allows much more precise argument catching what seems to be quintessential for bio-control. Liquid crystals allow weak but coherent electric fields making possible ohmic currents at atomic space-time sheets which together with the magnetic super current circuitry could form many-sheeted quantum control circuitry which in ionic flow equilibrium amplifies very small densities of ions at super-conducting magnetic flux tubes to much higher densities of ions at the atomic space-time sheets. MEs could induce various quantum transitions of ions (perhaps also molecules like enzymes) at magnetic flux tubes in quantum coherent manner and even amplify them to quantum phase transitions. This would make possible very effective biochemical control. Body consciousness could be assigned with the magnetic flux tube circuitry and magnetic quantum phase transitions whereas higher level consciousness would correspond to quantum transitions of super-symplectic representations assignable to the boundaries of MEs. The difference would be that magnetic states reduce to states defined in 3-surface whereas super-symplectic states are genuine quantum gravitational states defined in the space of 3-surfaces: thus body consciousness and "our" consciousness would correspond to totally different abstraction levels (quantum field theory and quantum TGD as a matter of fact!).

If one accepts the idea that living matter resides in the intersection of real and p-adic worlds it becomes easy to accept the hypothesis that evolution corresponds to p-adic evolution. This hypothesis is testable. The reason is that p-adic length scale hypothesis selects very few physically interesting primes in the range of biologically interesting length scales and makes the notion of p-adic evolution very predictive. The hierarchy of the p-adic primes should also correspond to the hierarchical structure of consciousness.

p-Adic length scale hypothesis can be actually applied at two levels. p-Adic length scale hypothesis follows if the proper time distance between the tips of CD come as octaves of CP_2 time scale. An argument based on light-like randomness implies p-adic length scale hypothesis stating that primary p-adic length scales L_p are proportional to $\sqrt{p}$, $p \simeq 2^k$, whereas the temporal and spatial size of CD is proportional to $2^k \simeq p$ and corresponds to $L_{p,2} = \sqrt{p}L_p$. This implies that elementary particles are accompanied by macroscopic time and length scales [K69] meaning a hidden connection between elementary particle physics and macroscopic physics. For instance, electron corresponds to the time scale.1 second defining the fundamental biorhythm.

The emergence of space-time sheets having size given by the primary p-adic length scale $L(k)$ and accompanied by secondary p-adic length scales should have been a dramatic breakthrough in evolution since new level of space-time sheet hierarchy emerged. In the following this hypothesis will be tested. In fact, it turns out that the scales identified as electron Compton lengths $L_e(k) = \sqrt{5}L(k)$ are more relevant in biology. As a matter of fact, all writings before 2004 have misidentified $L(k)$ as $L_e(k)$. The interpretation could be in terms of bio-superconductivity based on electron Cooper pairs. The consideration is however restricted to the primary p-adic length scale hypothesis.

11.3.8 How To Apply P-Adic Length Scale Hypothesis?

The p-adic length scale $L(k)$ can be replaced with the electron Compton length scale $L_e(k) = \sqrt{5}L(k)$, which defines natural candidates for biologically important length scales. $L_e(151) \simeq 10^{-8}$ meters corresponds to cell membrane length scale and one has

$$L_e(k) = 2^{(k-151)/2} L_e(151) \ .$$

The problem is to find whether there is some precise geometric criterion fixing the p-adic prime of the structure and what this criterion is. It must be emphasized that the upper bound for the size of a structure with given k might be dynamically determined. At least, join along boundaries/flux tube condensates formed from basic objects with size of order $L_e(k)$ seem to be possible. In [K38] this kind of criteria were discussed and the conclusion was that join along boundaries condensate might have size which is hundred times larger than the size of the basic building block (say atom).

Even if the criterion determining the p-adic prime of basic structure is purely geometric, one has still the problem of deciding what the precise form of the criterion is. In case of most layered structures there seem to be no special problems (note however the problem with epithelial sheets!).

1. The lower limit for the thickness of the structure should corresponds to $L_e(k)$. This criterion indeed works nicely for all layered structures. In case of spherical and cylindrical structures the criterion is not so obvious. Should one interpret p-adic length scale as the minimum radius or diameter? It seems that the identification of the p-adic length scale as a lower limit for the radius of the structure is the correct one.

2. One should have also criterion giving lower bound for k in case that the structure is irreducible in the sense that it is not join along boundaries condensate of nearly identical basic units. A possible criterion is that if the irreducible structure contains cube of side $L_e(k)$ then the p-adic prime must be at least k. This would mean that $L_e(k)$ is the length scale of a spherical structure up to diameter $d = \sqrt{3}L_e(k)$,

k	127	131	137	139	149
$L_E(k)/10^{-10}m$	.025	.1	.8	1.6	50
k	151	157	163	167	169
$L_e(k)/10^{-8}m$	1	8	64	256	512
k	173	179	181	191	193
$L_e(k)/10^{-4}m$	.2	1.6	3.2	100	200
k	197	199	211	223	227
$L_e(k)/m$	.08	.16	10	640	2560

Table 11.1: The scales $L_e(k) = 2^{k-151}L_e(151)$, $p \simeq 2^k$, k prime, possibly relevant to biophysics. The last 3 scales are included in order to show that twin pairs are very frequent in the biologically interesting range of length scales. The length scale $L_e(151)$ is take to be thickness of cell scale, which is 10^{-8} meters in good approximation.

The problem becomes especially acute in case of cell and epthelials sheets consisting of two cell layers. The twin pair $(167, 169)$ is especially natural looking in this respect and would suggest that the p-adic length scale of cell is $L_e(167)$. $L_e(169)$ would in turn be the p-adic length scale associated with the epithelial sheets formed from two cell layers abundant in living system (skin and cavities surrounding organs, sensory organs, nuclei of brain).

This looks nice. It is however known that the sizes of cells vary in wide limits. The cells of bacteria have size about one micrometer, the lower bound for neuron size is 5 micrometers, red blood cells have size of 8 micrometers. Some sources mention the size of 20 microns as the size of a typical cell! Egg has macroscopic size. Also neurons can have gigantic sizes. Thus it looks very questionable to assign $k = 167$ with these cell sizes. and would be in conflict with the spirit of p-adic evolution hypothesis. The solution of the dilemma is simple. Cell differentiation means also p-adic evolution of the cell so that the p-adic prime of cell can grow during the development. Of course, the p-adic prime characterizing mature cell grows also in the course of evolution. Thus the p-adic prime of cell would give a measure for its level of evolution. Egg is certainly much more evolved system than bacterium.

The criterion $d < \sqrt{3}L_e(k)$ for the size of cells corresponding to $L_e(k)$, implies that cells with diameters in the range $(2.2, 9)$ micrometers should correspond to $k = 167$. Accepting this criteria bacteria would have $k = 163$ and smallest neurons with diameters in the range $5 - 9$ micrometers and red blood cells would have $k = 167$. Cells with size of 20 microns (typically neurons) correspond to $L_e(169)$. One can however quite well consider the possibility that the length scales characterizing bacteria, blood cells and neurons correspond to $k = 167, 169$ and 173.

It seems that there are epithelial sheets consisting of two cell layers which are considerably more thicker than 5 microns suggested by the simplest guess. Rather it seems that 5 micron serve only as a lower bound for the thickness of the epithelial sheets and it is this prediction which is testable. The natural explanation is based on evolution leading to the increase of the mature cells but leaving the topology unchanged. "Ontogeny recapitulates phylogeny" principle suggests that the evolution is repeated during the development of individual organism. Epithelial sheet is a join along boundaries condensate of more or less identical cells. flux tubes are gap junctions now. At some stage of the growth join along boundaries/flux tube condensate must have had critical thickness of order $L_e(169)$. At this stage a phase transition leading to generation of new $k = 169$ space-time sheet occurred and led to the separation of the structure as separate geometric space-time sheet. After than cell growth continued and the p-adic prime of cells could grow in a phase transition manner to $k = 169$ at some later stage. Of course, also larger p-adic primes are possible. Note that the p-adic prime of cells and of the epithelial sheet can be also same.

To make things even more complicated, biologists tend to determine the size of cell by dividing the area spanned by cells by their number so that the size of the cell is actually determined as the area occupied by the cell! Therefore one must be very cautious with the numbers claimed to give "cell size".

11.3.9 Are Also Gaussian Primes And Eisenstein Primes Important?

Besides ordinary primes also Gaussian and Eisenstein primes exists and it seems that one define the notion of G-adic and E-adic number fields. This makes these primes very interesting from the point of view of bio-systems.

Gaussian primes

Gaussian primes consist of complex integers $e_i \in \{\pm 1, \pm i+\}$, ordinary primes $p\ mod\ 4 = 3$ multiplied by the units e_i to give four different primes, and complex Gaussian primes $r \pm is$ multiplied by the units e_i to give 8 primes with the same modulus squared equal to prime $p\ mod\ 4 = 1$. Every prime $p\ mod\ 4 = 1$ gives rise to 8 non-degenerate Gaussian primes. Pythagorean phases correspond to the phases of the squares of complex Gaussian integers $m + in$ expressible as products of even powers of Gaussian primes $G_p = r + is$:

$$G_p = r + is \ \ , \ \ G\overline{G} = r^2 + s^2 = p \ \ , \ \ p \ \text{prime} \ \& \ \ p \ \ mod \ \ 4 = 1 \ \ . \tag{11.3.1}$$

The general expression of a Pythagorean phase expressible as a product of even number of Gaussian primes is

$$U = \frac{r^2 - s^2 + i2rs}{r^2 + s^2} \ \ . \tag{11.3.2}$$

By multiplying this expression by a Gaussian prime i, one obtains second type of Pythagorean phase

$$U = \frac{2rs + i(r^2 - s^2)}{r^2 + s^2} \ \ . \tag{11.3.3}$$

Eisenstein primes

Whereas Gaussian primes rely on modulo 4 arithmetics for primes, Eisenstein primes rely on modulo 3 arithmetics. Let $w = exp(i\phi)$, $\phi = \pm 2\pi/3$, denote a nontrivial third root of unity. The number 1-w and its associates obtained by multiplying this number by ± 1 and $\pm i$; the rational primes $p\ mod\ 3 = 2$ and its associates; and the factors $r + sw$ of primes $p\ mod\ 3 = 1$ together with their associates, are Eisenstein primes. One can write Eisenstein prime in the form

$$\begin{aligned} E_p(r,s) &= r - \frac{s}{2} + is(r - \frac{s}{2})\sqrt{3} \ \ , \\ r^2 + s^2 - rs &= p \ \ . \end{aligned} \tag{11.3.4}$$

What might be called Eisenstein triangles correspond to the products of powers of the squares of Eisenstein primes and have integer-valued long side. The sides of the orthogonal triangle associated with a square of Eisenstein prime $E_p(r,s)$ have lengths

$$(r^2 - rs - \frac{s^2}{2} \ \ , \ \ s(r-s)\frac{\sqrt{3}}{2} \ \ , \ \ p = r^2 + s^2 - rs) \ \ .$$

Eisenstein primes clearly span the ring of the complex numbers having the general form $z = (r + i\sqrt{3}s)/2$, r and s integers.

Of course, there exists infinite number of extensions of rational numbers and each of them allows the notion of prime number in appropriate sense.

G-adic and E-adic number fields

It seems possible to generalize the notion of p-adicity so that could speak about G-adic and E-adic number fields. The properties of the Gaussian and Eisenstein primes indeed strongly suggest a generalization for the notion of p-adic numbers to include what might be called G-adic or E-adic numbers.

1. Consider for definiteness Gaussian primes. The basic point is that the decomposition into a product of prime factors is unique. For a given Gaussian prime one could consider the representation of the algebraic extension involved (complex integers in case of Gaussian primes) as a ring formed by the formal power series

$$G = \sum_n z_n G_p^n \ . \tag{11.3.5}$$

   Here z_n is Gaussian integer with norm smaller than $|G_p|$, which equals to p for $p\ mod\ 4 = 3$ and $\sqrt{p}$ for $p\ mod\ 4 = 1$.

2. If any Gaussian integer z has a unique expansion in powers of G_p such that coefficients have norm squared smaller than p, modulo G arithmetics makes sense and one can construct the inverse of G and number field results. For $p\ mod\ 4 = 1$ the extension of the p-adic numbers by introducing $\sqrt{-1}$ as a unit is not possible since $\sqrt{-1}$ exists as a p-adic number: the proposed structure might perhaps provide the counterpart of the p-adic complex numbers in case $p\ mod\ 4 = 1$.

   Thus the question is whether one could regard Gaussian p-adic numbers as a natural complexification of p-adics for $p\ mod\ 4 = 1$, perhaps some kind of square root of R_p, and if they indeed form a number field, do they reduce to some known algebraic extension of R_p?

3. In case of Eisenstein numbers one can identify the coefficients z_n in the formal power series $E = \sum z_n E_p^n$ as Eisenstein numbers having modulus square smaller than p associated with E_p and similar argument works also in this case.

4. What is interesting from the physics point of view is that for $p\ mod\ 4 = 1$ the points G_p^n and E_p^n are on the logarithmic spiral $z_n = p^{n/2}exp(in\phi_0/2)$, where ϕ is the Pythagorean (Eisenstein) phase associated with G_p^2 (E_p^2). The logarithmic spiral can be written also as $\rho = exp(nlog(p)\phi/\phi_0)$. This reminds strongly of the logarithmic spirals, which are fractal structures frequently encountered in self-organizing systems: perhaps G- and E-adics might provide the mathematics for the modelling of these structures.

5. p-Adic length scale hypothesis should hold true also for Gaussian primes, in particular, Gaussian Mersennes of form $(1 \pm i)^k - 1$ should be especially interesting from TGD point of view. The scale considered below is electron Compton length or time as function $L_e(k) = \sqrt{5}L(k)$ of p-adic prime $p \simeq 2^k$.

   (a) The integers k associated with the lowest Gaussian Mersennes are following: $2, 3, 5, 7, 11, 19, 29, 47, 73, 79,$ $k = 113$ 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.

   (b) The primes $k = 151, 157, 163, 167$ define perhaps the most fundamental biological length scales: electronic Compton length $L_e(k)\sqrt{5}L(k)$ corresponds for $k = 151$ to the thickness of the cell membrane of about 10 nm and for $k = 167$ to cell size about 2.56 μm. This strongly suggests that cellular organisms have evolved to their present form through four basic stages.

   (c) $k = 239, 241, 283, 353, 367, 379, 457$ 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 super-astronomical time and length scale.

6. Eisenstein integers form a hexagonal lattice equivalent with the root lattice of the color group $SU(3)$. Micro-tubular surface defines a hexagonal lattice on the surface of a cylinder which suggests an interpretation in terms of E-adicity. Also the patterns of neural activity form often hexagonal lattices.

Do Gaussian Mersennes define "miracle frequencies" in living matter?

Ordinary and Gaussian Mersenne primes are of special importance in elementary particle length scales. All charged leptons, atomic nuclei, hadrons and intermediate gauge bosons correspond to ordinary or Gaussian Mersennes. The number theoretical, and there are reasons to assume that also biological, miracle is that there are four subsequent Gaussian Mersennes in the biologically most interesting length scale range. The values of k for these length scales L_p, $p \simeq 2^k$, k prime, are $k = 151, 157, 163, 167$ and correspond to the scales $L_e(k)$ given by 10 nm, 80 nm, 640 nm, and 2560 nm. The next p-adic length scale is also very special and corresponds to $k = 13^2 = 169$ which is not prime but a power of prime and very rare as such. It is quite possible that neutrinos could metastably topologically condense at these length scales so that one would have four metastable neutrino physics besides the stable one corresponding to $k = 169$ (this on basis of the data about neutrino mass squared differences [K56].

The photon energies corresponding to these Compton length scales are $E(151) = 124.0$ eV (UV), $E(157) = 15.5$ eV (UV), $E(163) = 1.9375$ eV (red light) and $E(167) = .4844$ eV (near infrared). The energy corresponding to $k = 169$ is $E(169) = .2422$ eV. One must notice that there is few per cent uncertainty related to an overall scaling of length scales and energies. These energies indeed seem to correspond to biologically important photon energies.

1. $E(163) = 1.9375$ eV corresponds to wavelength of 640 nm which is with.6 per cent accuracy equal to the wave length 644 nm of the photon absorbed in photosynthesis associated with chlorophyll b). For chlorophyll a) the wavelength is 680 nm and deviation is 6 per cent. This suggests that photosynthesis leads to a generation of positive energy ME representing the stored energy and having length of near to $L(167)$.

2. From the yield of 48 kJ/mole of energy in ADP-to-ATP transformation, .4976 eV corresponds to the energy liberated when ATP decays to phosphor atom and ADP and is few per cent higher than $E(167) = .4844$ eV. In the spirit of the topological self-referentiality, one might play with the thought that also the stored energy, rather than only binding energy, is represented topologically. If so, this energy might be simply stored as positive energy ME carrying this energy disappearing when ATP gives up its energy. It is unclear whether the vibration energy quantum .52 eV of water hydrogen bond could relate to $E(167)$.

   In [K22] a model for ATP as a universal "energy currency" is developed. The model is based on the hypothesis that $E(167)$ MEs, rather than theoretically and empirically questionable high energy phosphate bonds, serve as the energy currency. This leads also to a model for the coherent locomotion relying on the assumption that the hydrogen ion current accompanying the phosphorylation of ADP molecules to ATP molecules is generated by the leakage of the protonic supra currents from the flux tubes of Earth's magnetic field to the atomic space-time sheets. The macroscopic quantum coherence of the protonic supra currents allows to understand the coherency of the locomotion, which is miracle in the framework of the standard biochemistry.

3. $k = 169$ corresponds to energy $E(169) = .2422$ eV and belongs to the region of hydrogen bond energies, which depend on which kind of molecules hydrogen bond connects with each

other. The range of weak hydrogen bond energies is $.13 - .3$ eV and in the near infrared. Also strong hydrogen bonds with energies extending up to 1.6 eV are possible but the hydrogen bonds associated with the biological molecules such as those connecting the DNA nucleotides are weak. The maximum binding energy for water hydrogen bond equals to $E(169)$ with one per cent accuracy. Notice however that hydrogen bond energy depends on its environment: typically the energy of the first bond in DNA is largest which gives rise to what might be called zipper effect. Negative energy MEs with this frequency should be very important and allow better understanding of the collective properties of water. Sol-gel transition involves the generation of hydrogen bonds and thus $k = 169$ MEs might be involved with this transition. Hence it would be interesting to look for the effects of coherent light with this frequency on water and to the sol-gel phase transition and its reversal. Also irradiation of DNA by photons with energy $E(167)$ might yield interesting effects. It deserves to be noticed that $E(169)$ which correspond rather nearly to the hydrogen bond energy is liberated together with the corresponding momentum when only the second member of $k = 167$ ME pair liberates its energy.

4. What about the miracle frequencies in ultraviolet? A not very plausible possibility is that these frequencies are associated with atomic transitions. They could also correspond to energies associated with structures with corresponding lengths. For $k = 151$ MEs parallel to lipids of cell membrane are a possible candidate and it is known that the charging of the mitochondrial energy batteries occurs at its membrane. $k = 163$ and $k = 167$ seem to be related to metabolism and one can wonder whether the same could hold true for all the miracle length scales.

   (a) Perhaps the simplest possibility is that MEs with length of $L(167)$ are in question but em field corresponds to $n = 2^8 = 256$ harmonic serving as a topological correlate for a Bose-Einstein condensate of 256 photons with energy $E(167)$. During the discharging of the mitochondrial energy battery the value of n would gradually decrease. During the charging process the reversal of this process would occur. It is also possible that the notion of momentum battery makes sense. During discharging coherent momentum would be given to the bio-molecules involved. This could make possible coherent locomotion at the cellular level.

   (b) If one assumes that also 124.0 eV and 15.5 eV correspond to minimum length MEs representing energy packets, one ends up to an alternative idea about how metabolism might work. 124 eV bunches of energy with length equal the cell membrane thickness could be first divided to 8 bunches of 15.5 eV at the membrane of the mitochondria, then these bunches could be divided to.19 eV bunches and finally.48 eV bunches would result. This would be like wares coming to a market store in big packets containing smaller packets containing... Now however every sub-packet of the energy packet have larger size that the packet by uncertainty principle. The problem here is that rather complex topological processes are needed to liberate the energy in this case.

To sum up, the study of the effect of the "miracle frequencies" in living matter might be very revealing concerning the understanding of the bio-control and demonstrate unexpected effects.

11.3.10 P-Adic Length Scale Hypothesis And Molecular Evolution

As far as DNA determines the structure of living systems, the evolution of living systems reduces to molecular evolution at the level of DNA. The p-adic primes relevant to molecular evolution span essentially the same range of the length scales as the p-adic primes related to the body since, at least in human, total length of DNA in single chromosome is of order centimeter.

The pair $k = 137, 139$: atoms and simple molecules

The scales associated with $k = 137, 139$ form a twin pair related by a factor two. These length scales are given by $.75 \times 10^{-10}$ meters and 1.5×10^{-10} meters if $L(151)$ is taken to be 10^{-8} meters.

It is interesting to look what the p-adic length scales of typical simple bio-molecules are when the their size is defined as their diameter. Using Angström as unit the diameters are $d(Mg) = 1.44$,

$d(Na) = 1.96$, $d(Ca) = 2.0$, $r(Ca) = 2.74$, $r(H_2O) = 2.74$. The criterion $d > \sqrt{3}L(k)$ gives an upper bound for the p-adic length scale for the object of diameter d. Applied to $k = 139$ this gives $d > 2.7$ Angstrom for objects having $k = 139$. Only Ca and H_2O satisfy this criterion and thus they represent $k = 139$ level of molecular evolution.

One can say that light atoms belong to the lowest level of evolution defined to start from $k = 137$ objects. Calcium represents second level of atomic evolution. Interesting possibility proposed already earlier is that outer electrons of Calcium drop on non-atomic space-time sheet $k = 139$ and this indeed makes Ca object involved object consisting of two space-time sheets. H_2O represents the second level of evolution of molecules. It is rather remarkable that Ca and H_2O molecules are indeed in central role in control and coordination protein conformations. For instance, gel-sol phase transition, which seems to be basic process at intracellular level, involves Ca^{++} ions in essential manner.

Tubulins, which are the basic building blocks of micro-tubule, have diameter of 4 nm, which is below the critical diameter of $d = \sqrt{3} \times L(149) \simeq 8.75$ nm. Also the size of tubulin dimer about 8 nm seems to be slightly below the critical size.

The building blocks of DNA strand and double strand have radii of order 1 Angstrom and single strand corresponds to $k = 137$, whereas molecule pair in double strand corresponds to $k = 139$ respectively. For $L(151) = 10^{-8}$ meters, DNA molecule in double helix corresponds to a length of 3.4 $A \simeq 1.13 \times 2 \times L(139)$ of the double helix. This is quite near to $4 \times L(137)$. This suggests that one could perhaps fix the over all normalization of p-adic length scale by requiring that DNA triplet corresponds precisely to $4 \times L(137)$. This gives

$$L(151) = 108.8 \times 10^{-8} \text{ meters} .$$

That single DNA would correspond so precisely to a multiple of p-adic length scale would not probably be an accident.

Since DNA and protein molecules are obviously at quite high level of evolution it seems that the length of the molecule is what determines the value of the corresponding p-adic prime. Thus the evolution maps to the evolution of the p-adic length for DNA molecules! Thus the molecular length of $L(149) = 5$ nanometers should have been the first breakthrough in the molecular evolution (lipid layer of the cell membrane by the assembly of micelles of the liquid crystal!), which was followed rapidly by additional breakthroughs. It is obvious that the evolution reduces in well defined sense to the evolution of DNA sequences. This aspect of evolution will be discussed separately later.

p-Adic evolution of DNA

p-Adic evolution should involve two aspects.

1. The increase of the p-adic length scale characterizing the basic DNA modules. This suggest the classification of the basic building blocks of the genome by the p-adic length scale associated with the corresponding DNA sequences.

2. The fractal evolution involving emergence of longer p-adic length scales characterizing the size of the space-time sheets to which basic DNA sequences had # contacts. Thus the lengths of introns and exons are not expected to correlate with the p-adic scale of the space-time sheet to which they possibly have # contacts. Rather, same gene can have # contacts to arbitrarily large space-time sheets.

Consider first the critical lengths of the basic program modules. The lengths $L(149), L(151), L(157), ...$ of gene or DNA sequence might mean the emergence of something genuinely new in the evolution. This length scale hierarchy expressed in terms of $L(137)$ comes in powers of 2 as $N_{137} = 1, 2, 64, 128, 2^{10}, 2^{13}, 2^{15}, ...$

Single nucleotide pair corresponds to in double helix to distance of .34 nanometers which is larger than the length scale of $L(139)$. The structure of the double helix is such that there is a periodicity of 3.4 nanometers: this means that basic period corresponds to 10 nucleotides. This implies that 5 DNA triplets correspond to a length of 5.05 nanometers, which equals to p-adic length scale $L(149)$ if $L(151)$ is defined to be $L(151) = 10.2$ nm. $L(149)$ corresponds to the thickness of the lipid layer of cell membrane and $L(151)$ corresponds to 10 DNA triplets, to the thickness of the cell membrane and the basic period of DNA sequence when DNA triplet is regarded as a basic unit. Perhaps this periodicity is not accident but has deeper meaning possibly related to the periodicity of phase variable associated with DNA. The lengths of DNA sequences corresponding to p-adic length scale $L(k)$, $p \simeq k$, k power of prime are $N(DNA) = 2^{k-149} \times 5$ DNA triplets.

This means that the critical numbers of DNA triplets possible leading to the emergence of qualitatively new properties of organism are given by

$$\begin{aligned} N(DNA) &= 2^{(k-149)/2} \times 5 \ , \\ k &\in \{149, 151, 157, 163, 167, 169, 174, 179, 181, 191, 193, ..\} \end{aligned} \qquad (11.3.6)$$

The few lowest critical values of DNA triplets in gene are

$$N(DNA) = n \times 5 \ ,$$
$$n = 1, 2, 2^4 = 16, 2^7 = 128, 2^9 = 512, 2^{10} = 1024, 2^{12}, 2^{15}, 2^{16}, \cdots$$

The steps of this hierarchy resembles bring in mind the evolution for the length of the basic memory unit of computer memory! One must however notice that 5 DNA triplets seems to serve as a basic unit.

The emergence of new p-adic length scales could have meant emergence of new levels of modularization in the genetic program and it is interesting to look these numbers from this point of view.

1. One could think that short sequences of precursors of DNA, mRNA and tRNA molecules were generated spontaneously by self-assembly. This implied automatically the generation of amino-acids by the more primitive counterparts of transcription and translation processes. The lengths of DNA molecules began gradually grow and at the critical lengths of DNA corresponding to p-adic length scales dramatic new effects emerged. Also new space-time sheets emerged in the genome and the first guess is that this occurred for the critical sizes of the organism given by p-adic length scales.

2. Formation of lipid layers might have been the revolution occurring at this stage and since lipids should have had size of order $L(149)$. This revolution should have occurred when the length of the genome became longer than 5 DNA triplets and meant formation of lipid layers by self organization process known to occur in all liquid crystals: these layers were perhaps formed in the surface of water such that hydrophobic ends of proteins would have pointed out of water. Self organization presumably led simultaneously to the formation of double membranes having thickness $L(151)$ such that the hydrophobic ends of proteins pointed in the interior of the double membrane. Second revolution became possible when the number of DNA triplets became larger than 10 triplets so that proteins connecting cell interior of the double membrane to its exterior became possible and the control of ion concentrations became in principle possible. Transfer RNA (tRNA) has length of at most 27 triplets. Third revolution should have occurred $L(157)$, which corresponds to 80 triplets.

3. Smallest viruses possessing single strand of DNA have lengths between 15-100 nanometers and this suggest that genome correspond to p-adic length scales $L(149)$, $L(151)$ and $L(157)$. These length scales could characterize largest space-time sheets also present in genome. The building blocks of the envelope of viruses are genetically coded separately and self-assemble spontaneously so that only building blocks need to be coded. Therefore p-adic prime associated with the genome of virus could be smaller than that determined by the size of the virus. Viruses with two DNA strands have sizes between $250 - 1000$ nanometers. This suggest that the emergence of $k = 163$ length scale in the genome of virus was accompanied by the emergence of double stranded DNA. $k = 163$ is perhaps the largest p-adic length scale associated with virus genome.

4. Bacteria have typically sizes of $1 - 10$ micrometers. This suggests that $k = 163, 167, 169$ are the possible space-time sheets associated with the bacterial genome. The emergence of $k = 169$ could have meant the emergence of multicellulars and generation of epithelial sheet like structures consisting of two cell layers as well as emergence of introns and DNA cognition.

Consider now the typical lengths for the structures of the eukaryotic genome.

1. The presence of introns means that the length of a gene coding given protein plus introns is much longer than the DNA coding only the protein. The higher the evolutionary level of the species, the larger the fraction of the introns. For human genome the fraction of the exons is roughly 1 per cent. The typical length of hnRNA in nucleus is 6.000-8.000 np (nucleotide pairs) which corresponds to 18 micrometers and length scale $L(163)$ and $L(167)$. Even genes with length 20.000 np are possible and correspond to $L(169)$. The lengths of mRNA vary between 500-3.000 nucleotides corresponding to interval 1.7×10^{-7}-10^{-6} meters and length scales $L(157)$ and $L(163)$. RNA sequences coding typical protein consisting of roughly 300 amino acids are about 3×10^{-7} meters and correspond to $L(159)$.

2. Most of the highly repetitive DNA has rather short length between $5 - 300$ nucleotides. Introns having typically lengths between $10 - 1000$ nucleotide pairs. The length of ribosomal DNA is not longer than 10^3 nucleotides. These examples suggests that the basic program modules correspond to p-adic length scales between $L(139)$ and $L(157)$ and that introns and genes are built as fractal versions of the basic program modules possibly present in all plants and animals. The basic programs are chemically identical. They could however have wormhole contacts to increasingly larger space-time sheets so that organism possesses fractal like structural hierarchy. Alternatively, the contacts are on the space-time sheets with same p in all animals but the sizes of the join along boundaries condensates formed by fundamental expression domains depend on organism. The frequent occurrence of Hox genes in the genetic code of body parts of various sizes in the entire animal kingdom is consistent with both options.

Cell membrane and cytoskeleton

$k = 149, 151$ is the twin pair related to the lipid layers of cell membrane and cell membrane itself. Micro-tubuli having radius of 25 nanometers correspond to $k = 151$ structure. Also chromosomes have radius of order 25 nanometers.

The length scale associated with $k = 157$ is 80 nanometers. Cell cytoskeleton contains as its basic structural element the cylindrical structures formed by the triplets of micro-tubuli on a cylindrical surface having doublet of micro-tubuli at center. The size of this structure corresponds to $L(157)$. For viruses the diameter of the membrane envelope is between $80 - 120$ nanometers. Cell organelles contain smaller membrane bounded structures (christae, thylakoids, ...), which could correspond to the p-adic length scale $L(157)$.

It must be emphasized that DNA evolution occurs also in different direction and corresponds to the emergence of new space-time sheets to many-sheeted DNA. The number of these space-time sheets might serve as more important measure for the evolutionary level of organ than the length of the gene and distinguish between humans and dinosauri.

11.3.11 Evolution Of The Cellular Structures

Cells can be classified into prokaryotic cells having no cell organelles enclosed by membranes and eukaryotic cells containing this kind of cell organelles, which in turn contain further sub-cell organelles surrounded by membranes. The second distinction is division into plant and animal cells. Nanno-bacteria are still further potential but not yet established life form. Besides cell like life there are viruses enclosed by envelope like structure. Viruses are not however able to metabolize.

$k = 163$ and bacteria (prokaryotes)

The length scale associated with $k = 163$ is .64 micrometers. Bacteria have typically cell size of 1 micrometer and would thus have radius of order $L(163)$. Also substructures of collagen fibres in connective tissue have radius about $.5 - 10$ micrometers and might correspond to $L(163)$ and possibly larger p-adic length scales. Of course, evolution of these structures means that their p-adic prime has possibly increased. Also cell organelles like mitocondria, chloroplasts and nucleus could correspond to $k = 163$ length scale. The diameter of mitochondria is indeed of order 1 micrometer.

Evolution of the eukaryotic cellular structures

It is tempting to regard the evolution of cellular structures as gradual increase of p-adic prime and to classify primitive cellular life forms by their p-adic prime. The key observation is that various cell organelles are surrounded by membrane and cell organelles contains smaller organelles surrounded by membrane. There is thus 3-fold hierarchy of membrane like structures present. For instance, nucleus, mitochondria and cloroplast basic cell organelles inside plant cell and mitochondria and chloroplast contain smaller structures like cristae and thylakoids. This Russian dolls inside Russian dolls structure suggests strongly interpretation in terms of space-time sheets labelled by p-adic primes. Evolution of cell has proceded in steps. When new space-time sheet emerged some population of structures of the previous level remained confined inside the new space-time sheet. Some structures left out and remained possibly living fossils.

1. The first step would correspond to the generation of $k = 157$ structures enclosed by cell membrane (say cristae and thylakoids) with size not smaller than $L(157) = 80$ nanometers. The general model predicts that bacteria are preceded by a more primitive form of life corresponding to $k = 157$. Besides viruses and [I14, I50] correspond to this form of life: in fact, the sizes of nannobacteria are reported to be in the range $.2 - .6$ micrometers and thus correspond to p-adic length scale $k = 157$.

2. At the next step emerged the $k = 163$ structures (nucleus, mitochondria and chloroplasts) enclosed by cell membrane and containing structures. $L(163) = .64$ micrometers corresponds to the lower limit for the size of prokaryotes (bacteria) so that bacteria are living fossils from this period of evolution. The fact that bacteria lack membrane bound compartments is consistent with the assumption that they correspond to $k = 163$. The absence of internal membrane bound structures however suggests that they have evolved from $k = 157$ form of life by a gradual growth of cell size.

3. The next step was the emergence of $k = 167$ structures, eukaryotes, closed by a further cell membrane. These structures are the precedessors of animal and plant cells. No larger structures surrounded by cell membrane emerged anymore.

4. The emergence of $k = 169$ space-time sheets must have meant a dramatic breakthrough in the evolution since double cell layers emerged as new structures condensed at $k = 169$ space-time sheet. The emergence of $k = 169$ space-time sheet makes possible the generation of epithelial sheets as autonomous selves and must have led to a proliferation of structures. The explanation for the difference between plants and animals is that this evolutionary step did not occur in case of plants. The reason is trivial: plant cells are surrounded by a wall hindering the formation of flux tubes between plant cells.

It must be emphasized that these structures, once created continue to evolve and typically sizes can be considerably larger than the p-adic length scale of the simplest structure. Indeed typical cell size seems to vary between $10 - 100$ micrometers. The basic topological structure however reflects the evolution of these structures.

11.3.12 P-Adic Length Scale Hypothesis And Neural Evolution

It is tempting to try to identify the components of sensory experience in terms of the p-adic length scales involved. Both the identification for the quantum correlates of the sensory qualia and emotions and the model for cognition [K41, K43] relies on the hierarchy of p-adic space-time sheets representing selves and forming a master-slave hierarchy of weakly coupled super-conductors. Sensory experiences are parameterized by various magnetic transition frequencies serving as resonance frequencies for which Josephson currents induce "wake-up" of the sub-selves representing sensory mental images. A partial characterization for a component of conscious experience is in terms of p-adic length scales involved with the group of sub-selves, which are "awake" during a particular conscious experience.

The general rule helping to understand the general evolution of neural consciousness seems to be that the more emotional the experience is, the lower is the corresponding magnetic transition frequency. This is understandable if emotions are byproducts of sensory experiences resulting from the automatic comparison of subjective (real) memories and geometric memories (expectations, simulations). Thus the typical timescale of the experience measures how emotional the experience is: emotions are indeed long-lasting whereas the characteristic time scale of sensory experiencing is below .1 seconds.

p-Adic length scale hierarchy and components of conscious experience

The p-adic primes relevant above bacterium length scale are twin pair $k = 167, 169 = 13^2$, $k = 173$, twin pair $k = 179, 181$, twin pair $191, 193$, and twin pair $k = 197, 199$. Note that with single exception all length scales in this range relevant to the functioning of human brain have twin partner! The density of primes and twin primes (note however that $k = 169 = 13^2$ is power of prime rather than prime) is exceptionally large in this region. This implies that the number of p-adic hierarchy levels per length unit is exceptionally large. Already this observation sheds some understanding to the question why human brain is so miraculously structured system.

After $k = 199$ there is a huge gap in the distribution of twin primes: next pair $(227, 229)$ corresponds corresponds to length scale of 3 kilometers!

1. In TGD framework cognition is based on cognitive neutrino pairs associated with $k = 151$ defects of $k = 169$ neutrino super-conductor. Cognition making possible to assign names to experiences and thinking as internal speech involves the pair formed by the cellular space-time sheet ($k = 169$) and cell membrane space-time sheet ($k = 151$). Despite the short length scale involved, linguistic thought, being a critical phenomenon, is a latecomer in evolution. The model for many-sheeted DNA suggests that genes at chromosome space-time sheet, which also has $k = 151$, could represent our conscious beliefs [K55] and represent one form of Boolean mind realized in terms of cognitive neutrinos. The dramatic difference between eukaryotes and prokaryotes can be explained as the emergence of $k = 169$ space-time sheet and exon-intron degree of freedom making possible Boolean cognition and genetic representation of beliefs. Thus introns seen as " junk DNA" by hard-nosed materialists is absolutely crucial for consciousness in TGD framework!

2. Primary sensory experiencing corresponds to $k = 169$ at which Earth's magnetic field resides. Sensory modalities which are simple in the sense that they involve very few sub-modalities (vision, taste, tactile sense) can be parameterized in terms of magnetic transition frequencies of ions in Earth's magnetic field.

3. $k = 173$ space-time sheet is identified as a carrier of Earth's Z^0 magnetic field with strength roughly $g_Z B_Z \sim eB/16$ The emergence of this space-time sheet meant the emergence of olfaction with a rich repertoire of sub-modalities having as quantum-correlates the Z^0 magnetic transition frequencies of various particles (atoms, ions and even molecules). Geometric cognition based on the formation of geometric representations for the objects of perceptive field by generating mind like space-time sheets is related with the emergence of $k = 173$ and longer p-adic length scales. The long time scale (low magnetic transition frequency) associated with olfaction explains why olfaction is so emotional experience.

4. $k = 179$ and $k = 181$ form twin pairs and correspond to sizes of ocular dominance columns and double layered sheets formed by them. $k = 179$ would correspond to higher level geometric cognition implying decomposition of the perceptive field into objects.

5. $k = 181$ could integrate left and right cognition to stereo cognition. Stereovision is excellent example of this integration. Usually the right and left visual fields combine to single field and it is impossible to experience them as separate ones. Visual self is in a state of whole body consciousness. This requires entanglement of the left and right visual field. For instance, if person has been drinking too much, the situation changes. Visual field splits into two separate fields. The interpretation is that visual self contains two sub-selves and is not anymore in a state of whole-body consciousness.

Summation hypothesis for conscious experiences explains at least partially the existence of sensory homunculi in brain. Various sensory homunculi would provide maps sensory experience of self at given level to experience of self at the next hierarchy level. This kind of mapping would be necessary since given self forms average about the experiences of its sub-sub-selves. For instance, all experiences from the points of skin would average to single experience without this map at 2 levels above the primary sensory experience.

The stages at which the sizes of subunits of brain have reached critical size given by some p-adic length scale must have been meant dramatic boosts in the rate of the evolution.

Twin pair $(167, 169)$ and bi-layered epithelial sheets

Already bacteria form colonies but one can regard this as join along boundaries condensates having no internal structures. The size $L(167) = 2.22$ micrometers must have meant a decisive critical size in the evolution of cell. When this size of achieved, the formation of bi-layered epithelial sheets as double sheeted structures condensed on newly emerged $k = 169$ space-time sheet became possible and evolution of genuine multi-cellulars became possible. Cells continued still their own evolution and size of order 9 micrometers must have been landmark in the evolution of cell. It would be interesting to know whether there is some neurophysiological identification for this step.

In order to avoid confusion it must be emphasized that the sizes of many cells are much larger than $L(167)$, egg is extreme example of this. This can be understood as a result of evolution of cells which in their primitive form had size given by $L(167)$ leading to a larger p-adic prime characterizing the cell. In case of neurons the complexity of neuron indeed correlates with its size. Thus the proper interpretation of $L(167)$ is as minimal possible size of cell. Also other p-adic length scales should be interpreted in the same spirit.

$k = 173$, Cambrian explosion and field axis orientation columns of cortex

The proposed model for the hierarchy of consciousness predicts that the size $L(173)$ for basic unit of primitive brain could have been a threshold for the emergence of emotions (of course, also other interpretations are possible). The lower bound for neuron radius is $L(167) and sphere with radius$ $L(173) \simeq 2 \times 10^{-5}$ meters contains roughly $N = 512$ neurons. Actually the number is smaller since neurons are not tightly packed.

The Orch OR model of Penrose and Hameroff [J44] predicts that Cambrian explosion occurred, when critical neuron number about 300 (nematode worms! TGD in turn suggests that it was the emergence of $k = 173$ neuronal space-time sheets that led to Cambrian explosion. According to TGD, the emergence of micro-tubuli meant the emergence of vision making possible formation of cell societies. Of course, it is possible that primitive eye had the critical number of $N = 256$ neurons. Cambrian explosion meant the emergence of arthropods and several phyla which do not exist anymore [I102].

The obvious place for the identification of this kind of structures is cortex. The relatively small thickness of the cortex (about 1 mm) implies that curvature effects do not mask the local cylindrical symmetry. Cortex is indeed known to possess columnar organization. There are in fact several columnar structures. The first columnar structure [J53] in the visual cortex corresponds to the so called field axis orientation columns consisting of locally stripe like regions of cells, which preferentially react to the orientation of a bar of light in the visual field. The width of the stripes with fixed orientation is about $20 - 50$ μm [J53]. The condensation level in question might correspond to $k = 173$ since the lower bound for thickness is $L(173) \simeq 20$ μm.

Twin pair $(179, 181)$ and ocular dominance columns of visual cortex

$k = 179, 181$ forms also a twin pair of length scales. The emergence of brain substructures with size larger than $L(179) \simeq .16$ millimeters must have also meant an explosive stage in evolution. The emergence of $k = 181$ level must have boosted the this explosion further. Note that $k = 179$ cube contains 8^3 structures of size $k = 173$. Thus it can be regarded as a three-dimensional chess-board or 8-move simulation for ordinary chess. Perhaps it is not accident that chess-board has 8×8 squares! It would be interesting to find at what is the level of evolution at which single structural unit reached the size $L(179)$. The first possibility is that the emergence of $k = 179$ space-time sheets meant the emergence of insects. Insects are basically sensory experiences having more sense than we do but not too much brain. Perhaps the emergence $k = 181$ space-time sheets was related to the emergence of vertebrates and stereo-cognition. This evolution step meant that brain size began to grow rapidly.

Also this twin pair of p-adic length scales seems to be realized in brain. Besides orientation columns visual cortex contains also so called ocular dominance columns. Also other parts of cortex contain similar columnar structures. The thickness for ocular dominance columns seems to correspond to $k = 179$ whereas the thickness for a pairs formed by them corresponds to $k = 181$. Ocular dominance columns consist of cells reacting appreciably to the stimulus from the second eye only and form columnar structures [J53] with complicated cross section and become visible via a continued stimulation of one eye only. The typical width of the stripe in the region is about $.2 - .5$ mm.

The levels $k = 179$ and $k = 181$ forming a pair with $L(179) \simeq .16$ mm might be the relevant p-adic levels now. The ocular dominance columns associated with right and left eye alternate and the regions formed by right-left pairs of ocular dominance colums is natural candidate for the double layered structure at level 179 and corresponds to $k = 181$. Also the hypothesis that $k = 181$ space-time sheet is the level at which right and left cognition integrate to stereo cognition is suggestive.

Larger structures

Hypercolumns as Rubik cube type structures?

Visual cortex contains also larger structures, "hypercolumns" [J53], which form basic units for the processing of visual information (and sensory information in general). These structures have roughly the size of order 1 mm, the thickness of cortex, and contain few thousand neurons. This length scale does not correspond to directly to any p-adic length scale. A possible interpretation is as a Rubik cube type structures formed from $3^3 = 27$ $k = 181$ cubes. Structures consisting of 3 basic units are rather abundant in brain (for instance, structures consisting of 3 cell layers).

What is the interpretation of the pair $(191, 193)$*?*

Next structures correspond to the twin pair $k = 191, 193$. $L(191)$ corresponds to cube with size of 1 cm and $k = 193$ to a cube of 2 cm. Pituitary gland seems to be a structure allowing interpretation as pair of structures with size about 1 cm. It however seems that human cortex does not contain these kind of structures as moduli: the reason is simple: the thickness of cortex (grey matter) is only 1 millimeter.

Pair $(197, 199)$ *and brain lobes*

$k = 197$ and 199 form again a twin pair of length scales related by a scaling factor of two. Structures would have size of order $L(197) = 8$ cm and $L(199) = 16$ cm. Could one identify brain lobes as a binary structure related to this pair of p-adic length scales? After this twin prime there is a huge gap in the spectrum of twin primes which suggests that the length scale range covering biological important length scales is indeed exceptional.

11.4 Higher Levels In Biological Self Hierarchy

TGD not only predicts infinite hierarchy of selves but also strongly suggests that "me" as an intentional agent should be identified as my field body, or perhaps better to say, my magnetic body having an astrophysical size. Magnetic body would also serve as an intentional agent and controlling biological body by time mirror mechanism (see **Fig. ??** in the appendix of this book). An entire hierarchy of magnetic bodies is predicted since the flux quanta of each body part define corresponding magnetic body. Also the magnetic body of Earth should define a conscious unit, kind of Magnetic Mother Gaia perhaps responsible for some third person aspects of our consciousness. The role of the magnetic body would be like that of a manual of an electronic instrument, that is it would provide a higher level representation for the body and its environment. Magnetic body would also serve as template for the formation of bio-structures. Magnetic body would share the mental images produced by brain as symbolic representations of the sensory input. The basic theoretical arguments supporting the notion of magnetic body derive from p-adic physics as physics of intention and cognition. Also time mirror mechanism of long term memories and Uncertainty Principle applied to EEG provide support for the notion. Some experimental findings supporting the notion of field body are Libet's findings, the role of Schumann resonance frequency for consciousness about time delays of consciousness, and the effects em radiation on brain and living matter at cyclotron frequencies.

This section was written much before the emergence of the zero energy ontology. A first principle justification for the notion of magnetic body is provided by zero energy ontology predicting that primary p-adic length scales are accompanied by secondary p-adic length scales (as well as time scales). For instance, in case of electron the secondary time scale is.1 seconds and correspond to a length scale of order Earth's circumference. It is natural to assign this time scale to the flux tubes of the magnetic body. This aspect will not be discussed explicitly in the sequel but should be kept in mind.

11.4.1 Support For The Notion Magnetic Body

Theoretical support

1. EEG and Uncertainty Principle

There are good reasons to expect that EEG is accompanied by radiation, which in TGD framework has topological light rays as space-time correlates. Typical EEG frequencies correspond to wavelengths $\lambda = c/f$ which for which natural length scale unit is Earth size. Thus Uncertainty Principle suggests that structures of at least this size are involved with the self hierarchy associated with the brain.

2. p-Adic physics as physics of cognition

p-Adic physics as physics of cognition is a fundamental key idea of TGD inspired theory of consciousness. For long time I believed that p-adic-to-real transformations of space-time sheets realized as quantum jumps could serve as correlates for the transformation of intentions to actions allow deeper understanding of also psychological time as a front of p-adic-to-real transition propagating to the direction of the geometric future. It turned out that the mathematical realization of this idea might involve unsurmountable challenges and the natural vision is based on adeles: both reals and various p-adic number fields would be present and cognition would be present already at elementary particle level as also the p-adic mass calculations suggest.

Intentional behavior means that there is unpredictability in short time scales but predictability in long time scales because system can realize its long term plans and use its partially free will to cope with the changing challenges of the everyday life.

p-Adic topology differs radically from real topology in the sense that p-adically infinitesimal is infinite in real sense.

1. The rational values of real and p-adic embedding space coordinates correspond to the same points of the generalized embedding space (essentially union of real and p-adic embedding spaces for various values of p with rational points common to all number fields and also points, in particular points with algebraic number valued coordinates, shared by different number fields in a pair-wise manner identified).

2. The points, which are p-adically close to each other can have arbitrarily long real distance since the points x and $x+kp^n$, $k \in \{0, p-1\}$, become arbitrarily near to each other p-adically and arbitrarily far way in real sense as n increases for the p-adic topology characterized by prime p.

This means that intentionality and cognition are literally cosmic phenomena and evolution of cognition proceeds from long p-adic length scales to short ones in real sense (but from short to long scales in p-adic sense). The carving of a statue by starting from a rough sketch and adding details gradually is a good metaphor for what is involved. Development of any motor skill, say piano playing, is an excellent example of what happens.

Intentions are transformed to action in a phase transition changing p-adic space-time sheet to a real one. This process is most probable when real and p-adic space-time sheets have maximal number of common rational points. Hence one expects that intentions can be transformed to large space-time sheets and topological field quanta are best candidates for these space-time sheets. Pairs of positive and negative energy topological light rays and negative energy topological light rays generated in the dropping of particles to larger space-time sheets, provide an example realizations of intentions. Also wormhole magnetic fields consisting of pair of space-time sheets carrying magnetic fields of equal intensity and having opposite time orientations could be generated intentionally.

In many-sheeted space-time (see **Fig.** `http://tgdtheory.fi/appfigures/manysheeted.jpg` or **Fig.** 9 in the appendix of this book) particles topologically condense at all space-time sheets having projection to given region of space-time so that this option makes sense only near the boundaries of space-time sheet of a given system. Also p-adic phase transition increasing the size of the space-time sheet could take place and the liberated energy would correspond to the reduction of zero point kinetic energy. Particles could be transferred from a portion of magnetic flux tube portion to another one with different value of magnetic field and possibly also of Planck constant h_{eff} so that cyclotron energy would be liberated. In the following only the "dropping" option is discussed.

3. Time mirror mechanism of long term memories

TGD based model of long term memory requires no storage of memories of past to the brain of the geometric now. The memories are in the geometric past as dynamical self organization patterns and subject to changes.

1. In the case of active memory recall the desire to remember is communicated to the geometric past by sharing and fusion of mental images made possible by entanglement. In the case of episodal memories also the memory recall would result in this manner. For non-episodal memories the memory would be communicated from the geometric past using classical communications.

2. In the case of episodal memories active precisely targeted memory recall might be difficult since the entanglement with a correct mental image seems to require good luck. In principle it is possible to select the distance T to the geometric past where the memory comes from by selecting the fundamental frequency of ME.

3. The most natural manner to realize the time mirror mechanism is to regard magnetic body as the system communicating with the brain of the geometric past serving as mirror. The fundamental frequency $f = c/L$ of associated with a topological light ray of length L would naturally code for the time span of the long term memory as $T = L/c$ in the sense that only these memories would be communicated resonantly. Thus the distance from brain along magnetic flux tubes would code the time span of the memory. Long term memories with a span of order lifetime however require that the size of the magnetic body involved is measured in light decades.

Experimental support for the notion of magnetic body

The work of Blackman and other pioneers of bio-electromagnetism concerning the effects of ELF (extremely low frequency) em fields on brain [J25] discussed in [K37], provides dramatic support for this idea and also a concrete view about how brain manages to act as macroscopic quantum system. The currents generating EEG certainly create weak electromagnetic radiation fields which in TGD framework correspond to topological field quanta of size of Earth having natural coupling to the magnetic flux tubes.

The lowest Schumann frequency is roughly $c/2\pi R$, R radius of Earth, and equal to $\omega \simeq 8$ Hz. It is known that EEG frequencies are in the same frequency range as so called Schumann frequencies 8, 14, 21, ... Hz [F7] associated with the resonances of the electromagnetic fields in the 80 km thick wave cavity between Earth surface and ionosphere. The higher EEG frequencies seem to correlate with higher Schumann resonance frequencies: in particular, the frequencies 13 and 39 Hz which are also cyclotron resonance frequencies of Na_+, are very near to Schumann frequencies. Schumann frequencies vary in time and it has been found that also the variations of EEG frequencies correlate with this variation.

Magnetic perturbations near Schumann frequencies are known to have profound effects on human brain inducing altered states of consciousness and cortical instabilities such micro-seizures and epilepsies [J57, J66]. The photons generated by Josephson currents associated with macroscopic ionic BE condensates have wavelengths of order Earth size and the topological field quanta representing classically the radiation field have size of Earth.

The explanation of the effects related to water memory [I43, I31] suggests that similar magnetic effects appear at much wider frequency range than ELF frequencies which would mean that the super-conducting magnetic flux tube circuitries form a fractal hierarchy. The findings challenging the notions of ionic pumps and channels [I63] provide additional strong support for the notion of many-sheeted space-time and hierarchy of super-conducting of magnetic flux tubes. The evidence for the fractal hierarchy of magnetic flux tubes is discussed in [K21, K22].

These observations support the view that our "physical" body is only a dip of an iceberg and formed by the topological condensation of the bio-matter around electromagnetic topological field quanta serving as templates for the bio-structures.

11.4.2 Some Functions Of Magnetic Body

The magnetic bodies associated with various body parts, including cellular and even molecular magnetic bodies, could have several functions besides defining a hierarchy of intentional agents (for this aspect see [**?**]).

Topologically quantized classical fields as templates for the formation of bio-structures?

Magnetic bodies could serve as templates of bio-structures. For instance, blood circulation and central nervous system could have magnetic circuitries as templates. The web like structure formed by topological field quanta representing classical fields, in particular em fields, is reminiscent of structures formed by micro-tubuli and collagens forming the connective tissue of living systems. It has been already earlier suggested that magnetic flux tubes and other topological field quanta serve as templates for various bio-structures in the sense that ordinary matter is topologically condensed on the flux tube like structures. This would mean that living systems would be only part of much larger web formed by Earth's classical em field forming one particular sub-self (mental image!) of Mother Gaia.

The thickness for the flux tubes of Earth's magnetic field is about $2/\sqrt{eB} \simeq 4\times 10^{-6}$ meters. There is direct evidence for the hypothesis that ions in a magnetic field $B_{end} = 2B_E/5 = .2$ Gauss, where $B_E = .5$ Gauss is the nominal value of the Earth's magnetic field, form quantum states with the characteristic energies of order 10^{-14} eV and size of the orbit being of order $2/\sqrt{eB}$, that is cell size. It must be emphasized that B_{end} is not equal to B_E as I erratically believed for a long time. The model for dark matter as macroscopic quantum phases with Planck constant equal to an integer multiple of the ordinary Planck constant [K40] leads to the working hypothesis that B_{end} corresponds to the dark counterpart of B_E [K37].

For $B_{end} = 2/5B_E = .2$ Gauss interpreted as a dark magnetic field with $\hbar = 5\hbar_0$ carrying 2 units of flux (the unit is $h_5 = 5h_0$) and corresponding also to the p-adic length scale $L(169)$, the radius is 25 μm, the size of a large neuron. This possibly relates to the fact that the effects of ELF em fields are observed for vertebrates (for details see [K37]).

The coupling of the neuronal layers of cortex and perhaps all cells with the flux tubes of Earth's magnetic field could make possible entanglement between brain and Mother Gaia. If magnetic flux tubes of the dark counterpart of B_E have direct geometric coupling with brain one could perhaps understand the miraculous ability of birds and bees to navigate using Earth's magnetic field. The proteins navigating along micro-tubuli, cells navigating along collagen fibres and birds navigating along Earth's magnetic field lines would all be guided by higher level selves.

One could see also humans and the societies formed by them as continually self-organizing organs in the body of electromagnetic Mother Gaia. In this picture the narrow wave cavity of radius 80 km between Earth's surface and ionosphere could be like brain of Earth, which is very sensitive to the conditions of ionosphere and biosphere and has "biofeedback" coupling with living systems. The effect of oscillatory phenomena (sound, radiations and magnetic fields) at frequencies Schumann resonances on brain to be discussed below supports also the direct interaction of our brain with Mother Gaia via Earth's electromagnetic field.

It is interesting to notice that the ratio of the thickness of solar corona (10^6 m) to the radius of Sun (5×10^8 m), the height of the wave cavity of Earth (80 km) to Earth radius (7×10^6 m), the ratio of the thickness of grey matter of cortex (1 mm)to the size of human brain lobe (10 cm) as well as the ratio of the thickness of the cell membrane (10^{-8} m) to the radius of neuron (2.5×10^{-6}) have roughly the same value of order 10^{-2}. Could this mean that cell membrane, cortex, electromagnetic cavity of Earth and solar corona might have similar role in the self hierarchy? The general ideas about self-organization indeed support this view: boundary regions are subject to the most intense external energy feed and thus self-organize most effectively.

The web formed by topological field quanta of the classical em and Z^0 fields continues to arbitrary long length scales. For instance, the flux tube structure of solar magnetic field provides an explanation for the anomalously high temperature of solar corona and a model for solar spot cycle [K92]. Perhaps also Sun is a conscious self forming part of "Indra's net" representing electromagnetic and other classical fields of cosmos. Since the four CP_2 coordinates are the primary dynamical variables, one must consider the possibility that topologically quantized classical gauge fields and classical gravitational field could form rather independent sub-selves.

Dark magnetic fields and living matter

A considerable sharpening of the above discussed speculative picture came with the development of TGD inspired vision about dark matter as macroscopic quantum phases with quantized value of Planck constant having arbitrarily large values coming as integer multiples of the ordinary Planck constant [K40].

As often occurs, also the spotting of errors leads to important new insights. For years I erratically believed that the magnitude of the magnetic field assignable to the biological body is $B_E = .5$ Gauss, the nominal value of the Earth's magnetic field. Probably I had made the calculational error at very early stage when taking Ca^{++} cyclotron frequency as a standard. I am grateful for Bulgarian physicist Rossen Kolarov for pointing to me that the precise magnitude of the magnetic field implying the observed 15 Hz cyclotron frequency for Ca^{++} is .2 Gauss and thus slightly smaller than the minimum value.3 Gauss of B_E. This value must be assigned to the magnetic body carrying dark matter rather than to the flux quanta of the Earth's magnetic field. This field value corresponds roughly to the magnitude of B_E at distance 1.4R, R the radius of Earth.

Dark matter hierarchy leads to a detailed quantitative view about quantum biology with several testable predictions [K37]. The applications to living matter suggests that the basic hierarchy corresponds to a hierarchy of dark matter levels is labeled by the values of Planck constant having quantized but arbitrarily large values. For the most general option the values of $\hbar$ are products and ratios of two integers. The products of distinct Fermat primes and power of two are number theoretically favored values for these integers. p-Adic length scale hypothesis favors powers of two. The larger the value of Planck constant, the longer the subjectively experienced duration and the average geometric duration $T \propto \hbar$ of the quantum jump.

Each p-adic length scale corresponds to this kind of hierarchy. Number theoretical arguments suggest that the values of n for which quantum phase $q = exp(i2\pi/n)$ is expressible using only iterated square root operation are number theoretically preferred and correspond to integers n expressible as $n = 2^k \prod_n F_{s_n}$, where $F_s = 2^{2^s} + 1$ is Fermat prime and each of them can appear only once. The lowest Fermat primes are $F_0 = 3, F_1 = 5, F_2 = 17$. The prediction is that also n-multiples of p-adic length scales are possible as preferred length scales. The unit of magnetic flux scales up as $h_0 \rightarrow h = nh_0$ in the transition increasing Planck constant: this is achieved by scalings $L(k) \rightarrow nL(k)$ and $B \rightarrow B/n$.

$B = .2$ Gauss would corresponds to a flux tube radius $L = \sqrt{5/2} \times L(169) \simeq 1.58L(169)$, which does not correspond to any p-adic length scale as such. $k = 168 = 2^3 \times 3 \times 7$ with $n = 5$ would predict the field strength correctly as $B_{end} = 2B_E/5$ and predict the radius of the flux tube to be $r = 18$ μm, size of a large neuron. However, $k = 169$ with flux $2h_5$ would be must more attractive option since it would give a direct connection with Earth's magnetic field. Furthermore, the model for EEG forces to assume that also a field $B_{end}/2$ must be assumed and this gives the minimal flux h_5. Note that $n = 5$ is the minimal value of n making possible universal topological quantum computation with Beraha number $B_n = 4cos^2(\pi/n)$ equal to Golden Mean [K6].

An natural working hypothesis is that B_{end} defines the dark counterpart of the ordinary magnetosphere and that the relationship $B_{end} = 2B_E/5$ holds as a time average in the entire magnetosphere. The flux quanta of B_{end} would carry dark matter and would be responsible for the quantum control of the living matter.

Magnetic flux tubes and metabolism

Magnetic flux tubes could define super-conducting circuitry making possible a many-sheeted control of homeostasis: this aspect is discussed in [K49]. The hierarchy of magnetic flux tubes could also define many-sheeted lasers, and the dropping of particles to the larger space-time sheets would define a hierarchy of metabolic energy currencies as zero point kinetic energies liberated in the process. Process would also generate radiation at the harmonics of cyclotron frequencies at the larger space-time sheet. These frequencies could define a considerable part of EEG. Also fractally scaled up versions of EEG having similar band structure are predicted. The findings of Peter [I47] are consistent with this prediction [K19]. The dropping of particles to larger space-time sheets for population inverted lasers would be also ideal for the realization of bio-control by time mirror mechanism and make possible remote metabolism and remote motor control.

Magnetic flux tubes as Nature's own bio-laboratory

Magnetic flux tubes could be ideal structures for the isolation and purification of various bio-molecules, and make also possible precise targeting of the reactants to reaction volumes defined by the nodes of the magnetic flux tube circuitry. Purification is made possible by the weight of the molecule if quantum-classical correspondence holds true in the sense that a magnetic flux tube carrying super-conducting bosons of mass m deforms so that it runs along a classical orbit of the particle with radius proportional to m. This would make sense for a many-sheeted magnetic field for which the fluxes associated with the magnetic flux tubes along which particles move return along much larger space-time sheets and define the average magnetic field in which the particles move. This kind of Nature's own bio-laboratory might explain the miraculous selection of bio-molecules essential for the pre-biotic evolution. In accordance with the p-adic vision about the evolution of cognition, the evolution would have been proceeded from and guided by the magnetic flux tube structures of the Earth's magnetic field to the bio-chemical level [**?**] .

11.4.3 The Magnetic Fields Associated With Body Parts And Higher Levels Of Consciousness

The basic vision is that magnetic flux tubes containing ionic super-conductors, MEs carrying exotic representations of p-adic Super Virasoro algebra, and biological organisms live in a fractal symbiosis. MEs can induce cyclotron transitions amplified to quantum phase transitions inside magnetic flux tubes provided they have length above the wavelength defined by the cyclotron frequency. The exotic p-adic Super Virasoro representations with MEs have wavelength determined by the fundamental frequency which is of same order as the cyclotron frequency. The interaction of MEs and magnetic flux tubes by SQUID mechanism requires that magnetic flux of ME generates a current inside a circuit formed by magnetic flux tubes. Magnetic flux tubes to have arbitrary size scales below the size scale of ME.

Some body parts are carriers of static magnetic fields. The value of the static magnetic field associated with eye is slightly below 10^{-11} Tesla whereas the strength of Earth's magnetic field is about $.5 \times 10^{-4}$ Tesla. Also pineal gland ("third eye" also in a rather literal sense, see [K41]) contains magnetic material. Unfortunately I do know the value of the corresponding dipole strength: for a dipole having size of order micrometer the maximal dipole strength would be very roughly 10^{-9} times corresponding dipole strength for Earth's magnetic field which would mean field of order 10^{-13} T. Also head and entire body could act as static magnetic dipoles.

For purely sensory consciousness .1 seconds is the characteristic time scale and EEG is closely related with this form of consciousness. In case of B_e the magnetic cyclotron frequencies are in the range obtained by scaling the range of cyclotron frequencies in Earth's magnetic field by a factor about 2×10^{-7}. This means that the periods of the ionic cyclotron frequencies are roughly in the range 12 hours-1.6 years for ionic cyclotron frequencies corresponding to the range of frequencies $90 - 0.1$ Hz in Earth's magnetic field. These time scales are typical for the contents of higher level self consciousness involving self narrative. Notice however that these fields are perhaps not sufficiently weak for a self narrative in the time scale of several years.

The minimal thickness of the flux tubes for ULF selves associated with B_e would be roughly of the order of few millimeters, as one finds by scaling the radius for the flux tube of Earth's magnetic field which is about 5 microns.

Also bodily magnetic fields B_b could be involved. By scaling one obtains for the head's magnetic field an estimate $(mm/headsize)^2 B_e \sim 10^{-4} B_e$, which gives fT which is slightly above the thermal noise produced by body. The flux tube would have minimal thickness about 10 cm, the size scale of the head. The cyclotron frequency range would be scaled by a further factor of 10^4 factor meaning that the time scale range would be between 10 years and 10^4 years!

Could the flux tubes of bodily magnetic fields correlate with more abstract levels of self consciousness?

The previous observations combined with the general speculative vision about Indra's web of consciousness stimulate several questions and ideas relating to the role of various magnetic fields associated with body.

1. Could it be that the ULF selves associated with the ionic super-conductors residing at the flux tubes of the bodily magnetic fields B_e and B_b (notice also the static magnetic fields of pineal gland and of other organs) belong to the self hierarchy and represent higher level selves contributing to our non-sensory consciousness under ordinary circumstances? This translates to the question whether the flux tubes of the corresponding topological quantized magnetic fields are closed in a relatively small volume as in case of an ideal dipole field or whether part of flux tubes have astrophysical lengths.

2. The above arguments do not pose restrictions on the strengths of the magnetic fields. In case of Earth's magnetic field the magnetic flux tubes have sizes of order of the wavelength associated with a typical cyclotron frequency. Could it be that the interacting MEs and magnetic flux tubes have sizes comparable to the wavelength defined by cyclotron frequency? If this is the case for B_e and B_b, the sizes of flux tubes would be astronomical with light day serving as lower bound. One could see the flux tubes of B_e and B_b as kind of umbilical cords connecting human bodies with magnetic structures of astronomical size and perhaps also with other organisms. Could one assign the more abstract levels of human consciousness and long term memories with the ULF selves associated with both the flux tubes of B_e and B_b and with MEs? In this view biological organisms would be like sensory-motor organs of this magnetic super organism.

3. Could one possibly test this hypothesis in case of B_e by studying the interaction of ULF em fields with frequencies above the time scale defined by day? Is the daily rhythm somehow relevant at the level of these em fields? For instance, could the natural 24 hour period certainly associated with ULF em fields of eye define the analog of alpha peak in EEG? Could the strength of the magnetic fields of eye be seen as a result of adaptation to the daily rhythm or is it dictated by the size of eye and flux quantization (there is roughly unit flux over an area of order millimeter squared)?

Objection

The bodily magnetic field change with time if the location orientation of the magnetic dipoles are fixed with body. Already the rotation of Earth induces periodic rotation of the magnetic flux tubes B_e and B_b. The volitional motion during wake-up period induces further effects.

There are several ways to circumvent this objection.

1. The most convincing manner to avoid the objection is that the flux tubes relevant for ULF consciousness have size at least of order of the wavelength defined by the cyclotron frequency and thus of the same order of magnitude as the size of the corresponding MEs. In this scale the rotating motion for the end of the magnetic flux tube of B_e or B_b would have absolutely no significance and magnetic flux tubes would be somewhat like magnetic umbilic cords (like the tunnel involved with the NDE experiences connecting patient to the deceased relatives!).

2. If the magnetic flux tubes in question have sizes comparable or smaller than Earth size, the situation changes. Only in the very special case that the flux tubes rotate around Earth in the direction of equator, B_e and B_b could remain stationary and it makes sense to speak about stationary states.

3. One could also consider the possibility that magnetic flux quanta are layer like structures around Earth rather than rotating tubular structures, and have rotational symmetry with respect to the rotations around Earth axis so that it is body which is rotating with respect to these structures rather that these structures rotating with body. In this case it would make sense to assign cyclotron frequencies to the super-conducting ions in question since local magnetic states are certainly possible. In super-conductors of type I near critical temperature complicated layer like flux structures are indeed possible and in [K21, K22] it has been suggested that epithelial sheets formed by cell membrane inside cells correspond to this kind of flux structures.

The obvious question is how the rotation of Earth affects localized stationary states of the super-conducting ions inside co-rotating magnetic flux tubes with sizes smaller than Earth size. Does the description of the system in terms of cyclotron states make sense anymore? Quantum mechanically the ion in a stationary magnetic magnetic field is in radial degrees of freedom like a harmonic oscillator.

1. A simple analog system would be a harmonic oscillator rotating with an Earth and having an oscillation period which is longer than 12 hours. By separating center of mass degrees of freedom one finds that the particle in the rotating oscillator well feels besides the ordinary harmonic force a harmonic force $m\omega^2\overline{r}_{cm}$ which means that the complete solution to the equations of motion is superposition of the harmonic oscillator motion plus a periodic oscillatory term with the frequency of the external force. The average motion is therefore just the rotating harmonic oscillator motion.

2. In quantum case one has harmonic oscillator coupled to an external harmonic force having a frequency much larger than the oscillator frequency. Time dependent perturbation theory allows transitions only between the states whose energy difference $n\omega_0$ equals to the forcing frequency and transitions thus possible only if one has $\omega = n\omega_0$. Thus no quantum jumps would occur in the generic case.

3. The guess motivated by these considerations is that the magnetic state in a rotating magnetic field is in a good approximation obtained by applying time dependent rotation to the ordinary magnetic state and that in the time scale defined by the cyclotron frequency the average effects to the state cancel also now. Thus effective adiabaticity holds true.

Further questions related to vision

One can make several interesting questions related to vision and the magnetic fields of eye.

1. What is the role of the rapid eye movements during REM sleep, in particular during dreams? Could it be that the communication of long term memories from ULF level is involved with dreams and that the rhythmic eye movements are essential for establishing this communication?

2. The motor control associated with eyes is decoupled from the motor control of the remaining body. Therefore persons who are totally paralyzed can still move their eyes and can even communicate in this manner. Could the special role of the eye-motorics relate to the remaining ability to stay in contact with ULF selves associated with eyes?

3. What is the interpretation of the rays of light characterizing the visual perception of intense light. Perhaps there is some natural explanation for this but since I do not know about it, I can entertain myself with the idea that these rays could directly correspond to MEs representing rays of light and connecting me with the objects of the external world. The correspondence between sensory experience and reality would be amazingly simple, if this is true.

NDE experiences and magnetic consciousness

NDE experiences [J73, J69] involve vision in an essential manner. This suggests that the dominating component of NDE consciousness could correspond to ULF selves associated with B_e and or B_b and give rise to the typical bird's eye of view about own body involved with the OBE and NDE experiences. The cyclotron frequency time scale associated with B_b would indeed fit with the life review experienced in NDE experiences. Body would be seen by ULF selves in bird's eye of view through the magnetic flux tubes of B_e and B_b. There would be a strange resiprocity resembling to the resiprocity encountered in the techniques of radio communications where the antennae sending messages can also serve as receiving antennae. NDE experiences involve also meeting of the dead relatives. Magnetic flux tubes can connect patient also to other organisms. and it would not be too surprising if magnetic flux tubes starting from the body could serve as an umbilic cord connecting the patient with living relatives or magnetic structures representing deceased relatives.

NDE experiences involve also the experience of travelling through a tunnel. The tunnel is experienced also during epilepsy and migraine, during meditation and relaxed state of mind, and with certain drugs like LSD, philocybin and mescaline.

I have also personal "tunnel experiences" every-daily: when I close my eyes in a half-meditative state achieved by writing at computer terminal, I can see a dim flow consisting of points. Typically this flow enters to or emergences from a tunnel. It can be rotating spiral like flow or simple sink or source. Source or sink can be also linear structure. The experience is not stable and tends to fade away all the time, and after few minutes I am not anymore able to achieve it. During my great experiences this flow was much more complicated and completely visible and formed a stable background of the ordinary visual experience and of hallucinatory visual images.

There is however no experience of entering into the tunnel in this case so that the tunnel need not be the same as encountered in NDEs. I have pondered quite a many times about the possible interpretation of this background flow. The basic observation was that it resembles liquid flow to a very high extent. Liquid flows are usually incompressible in an excellent approximation and this means that the velocity field is divergence free. This is the basic property of also magnetic fields and means that magnetic flux through a circuit moving along magnetic flux lines is conserved. This has stimulated the obvious guess that the background flow indeed represents magnetic field. The question which I have not made is whether this magnetic field resides inside my brain or outside it. In light of the above considerations the most natural answer to the question is that the magnetic field visualized by the flow is precisely where it seems to be. The flow would represent nothing but the magnetic field associated with my own eyes or more probably head, or rather how the self associated with the flux tubes of this magnetic field experiences the world.

The thickness of the flux tubes of B_b would be roughly the size of the head and this fits with idea that the tunnel experience represents directly the magnetic flow without any scaling factors involved. The fractality of TGD Universe suggests that these magnetic fields contain flux tubes of stronger magnetic fields inside them, so that the tunnel experience would represent the flux tubes of these magnetic fields experienced as sub-selves by the ULF self contributing to my visual consciousness in this altered state of consciousness. Of course, it might well be that also during the ordinary consciousness the experiencer is this magnetic ULF self and that sensory input dominates the content of the conscious experience and creates the illusion about body as self. In the absence of a sensory input the contents of consciousness of a clinically dead person is determined by these magnetic field and bird's eye of view about body results.

What remains after the physical death could therefore be determined by the magnetic fields involved with body. Magnetic flux conservation allows configurations of the closed magnetic flux loops containing ionic super-conductors as the counterpart of soul continuing existence after death. Wormhole magnetic fields and p-adic variants of these magnetic fields would also make it possible to store information about the magnetic fields originally associated with body. The overall view suggesting itself that our bodies are like sensors and motor organs of a gigantic electromagnetic organisms of astrophysical size and represent its sub-selves (mental images). This interpretation conforms with the fact that in EMDR method rhythmic eye movements induce experiences involving the meeting of deceased relatives [J11].

The experimental study of what happens to the magnetic fields associated with eyes, head and other body parts after the physical death would obviously provide interesting information in this respect, perhaps one can someday even develop refined methods of communication with the deceased.

What about magnetic fields of heart?

The magnetic fields associated with eyes are not the only bodily magnetic fields with peak intensities higher than the non-static magnetic fields generated by brain. Heart generates a periodically oscillating magnetic field B_h of order $.5 \times 10^{-10}$ Tesla which is almost ten times higher than the static magnetic field generated by eyes. I do not know whether B_h contains a static component and if so, what is its strength. In any case, the absence of the static component means that the possibly super-conducting ions inside flux tubes of heart's magnetic field are in a periodically oscillating dipole field (most probably with respect to the geometric time!).

Also here my "great experience", which has turned out to be an extremely valuable repertoire of altered states of consciousness, provides an illustrative example. During the second great experience which lasted only one night, I experienced what might be called "heart consciousness". In the beginning of the experience my whole consciousness was filled by the rhythmic "..aqua-aqua-aqua..". It took some time to recognize that this rhythm was the rhythm of my own heart. Involved was also the mystical experience about the fundamental importance of water for life (said jokingly, heart is an organ specialized to deal with liquid!) and the precognition of the notion of infinite primes. Could it be that the MEs associated with heart dominated the contents of my consciousness during this experience.

Chapter 12

Possible Role of p-Adic Numbers in Bio-Systems

12.1 Introduction

In this chapter p-adic physics, p-adic length scale hypothesis, and the special features of p-adic numbers are discussed from the point of view of biosystems. The identification of p-adic physics as physics of cognition tentatively identified as a cognitive simulation of real physics is the basic philosophical quide line. Second key idea is that living matter in very general sense lives in the intersection of real and p-adic worlds making among other things possible negentropic entanglement so that Negentropy Maximization Principle drives the formation of increasingly larger structures with negentropic entanglement.

The justification of the p-adic length scale hypothesis in zero energy ontology (ZEO) is discussed and the application of the hypothesis is discussed: both primary p-adic length scales and secondary p-adic length scales emerging naturally in zero energy ontology are discussed and it is found that the secondary p-adic scales assignable to elementary particles are in general macroscopic so that a connection between elementary particle physics and macroscopic physics suggests itself. Small-p p-adicity is also highly attractive idea and it is demonstrated that dark matter hierarchy characterized by hierarchy of Planck constants provides a first principle realization of this idea.

The characteristic features of p-adic physics are due to p-adic ultra-metricity, p-adic non-determinism, and to some exotic properties of p-adic probability and are expected to characterize also cognition. It is however too early to take too strong views concerning the interpretation of p-adics. Therefore also speculative ideas about the role of p-adic numbers in biology, which are only marginally consistent with the cognitive interpretation, are discussed in the sequel.

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` [L13].

12.2 General Vision About Fusion Of RealandP-Adic Physics

12.2.1 P-Adic Mass Calculations As Original Motivation For P-Adic Physics

The basic motivation for p-adic physics was provided by successful p-adic mass calculations based on p-adic thermodynamics which is thermodynamics for conformal weight to which p-adic mass squared is proportional. The p-adic mass squared is mapped to a real number by canonical identification.

p-adic thermodynamics is justified by the randomness of the motion of partonic 2-surfaces restricted only by light-likeness of the orbit. It is essential that the conformal symmetries associated with the light-like coordinates of parton and light-cone boundary are not gauge symmetries but dynamical symmetries.

In p-adic thermodynamics scaling generator L_0 having conformal weights as its eigen values replaces energy and Boltzmann weight $exp(H/T)$ is replaced by p^{L_0/T_p}. The quantization $T_p = 1/n$ of conformal temperature and thus quantization of mass squared scale is implied by number theoretical existence of Boltzmann weights. p-Adic length scale hypothesis states that primes $p \simeq 2^k$, k integer. A stronger hypothesis is that k is prime (in particular Mersenne prime or Gaussian Mersenne) makes the model very predictive and fine tuning is not possible.

The basic mystery number of elementary particle physics defined by the ratio of Planck mass and proton mass follows thus from number theory once CP_2 radius is fixed to about 10^4 Planck lengths. Mass scale becomes additional discrete variable of particle physics so that there is not more need to force top quark and neutrinos with mass scales differing by 12 orders of magnitude to the same multiplet of gauge group. Electron, muon, and τ correspond to Mersenne prime $k = 127$ (the largest non-super-astrophysical Mersenne), and Mersenne primes $k = 113, 107$. Intermediate gauge bosons and photon correspond to Mersenne M_{89}, and graviton to M_{127}.

The value of k for quark can depend on hadronic environment [K60] and this would produce precise mass formulas for low energy hadrons. This kind of dependence conforms also with the indications that neutrino mass scale depends on environment [C19]. Amazingly, the biologically most relevant length scale range between 10 nm and 4 μm contains four Gaussian Mersennes $(1+i)^n - 1$, $n = 151, 157, 163, 167$ and scaled copies of standard model physics in cell length scale could be an essential aspect of macroscopic quantum coherence prevailing in cell length scale.

12.2.2 Questions Raised By The Success Of P-Adic Thermodynamics

p-Adic mass calculations raise several technical questions which in turn help to imagine the interpretation of p-adic physics.

1. Is the canonical identification I: $\sum x_n p^n \rightarrow \sum x_n p^{-n}$- the only possible manner to map p-adic mass squared values to real numbers or can one consider also more general mappings? Can one require that p-adic mass calculations are equivalent with their real counterparts with the quantization for the counterpart of the p-adic temperature forced by this equivalence? This requires that a p-adic rational m/n defined as a ratio of finite p-adic integers is mapped to a ratio $I(m)/I(n)$ of the images of these integers under the canonical identification rather than mapping the infinite p-adic power series of the rational to a real number. This would affect p-adic mass calculations but would have no dramatic effects in the case that the lowest contribution to mass squared is integer valued as it indeed is.

2. It is also possible to generalize canonical identification by expanding p-adic numbers in powers of p^k with coefficients being non-negative integers $n < p^k$. This form of canonical identification applied to the numerator and denominator of rational m/n to give $I_k(m)/I_k(n)$is especially suitable when the p-adic temperature is $T = 1/k$. Could one interpret the hierarchy of canonical identifications I_k defined in this manner in terms of a measurement resolution for mass squared (IR cutoff) defined as the p-adic length scale corresponding to p^k? p-Adic integer points $n < p^k$ correspond indeed as such to real integers as also do the rationals formed from this kind of integers. Quite generally, for $T = 1/k$ the mass scale of particles is $p^{-k/2}$ and very small.

These questions inspire further questions.

1. Canonical correspondence between p-adics and reals and its possible generalizations apply to probabilities. Could similar correspondence relate also p-adic and real space-time sheets? Could symmetries allow to identify preferred coordinates of the embedding space so that the general coordinate invariance would not be lost. Could it be enough for the generalized canonical identification to respect the fundamental space-time symmetries in the IR resolution identified in terms of the pinary cutoff defined by p-adic length scale associated with p^k?

2. If both real and p-adic space-time physics makes sense what is the correspondence between them? Is it via common rational points of embedding space plus common algebraic points in preferred coordinates of the embedding space. This correspondence would be extremely discontinuous and the intersection of the p-adic and real worlds would be discrete. Or should

one apply canonical correspondence or some of its generalizations to the coordinates of the points in the preferred coordinate system forced by symmetries.

Could real physics in finite length and time scale resolution allow an elegant description in terms of p-adic physics in the sense that the lack of the well-ordering of p-adic numbers would be allowed below the resolution scale? Could one apply identification I_k applied to rational valued points in preferred coordinates so that one would have correspondence via common rationals below IR resolution scale and continuous map above this scale: this would mean a compromize between continuity requirement and space-time symmetries. These maps map arbitrarily distant common rational points of real and p-adic space-time sheets arbitrarily near to each other if their differ by a large power of p. Does this mean that canonical identification maps have interpretation in terms of holography?

3. What could be the interpretation of p-adic physics if it is a genuine part of physics at the space-time level? Could p-adic physics relate to cognition and intentionality, which are characteristics of living matter? If so, could living matter in some sense correspond to the intersection of p-adic and real worlds?

12.2.3 Zero Energy Ontology And P-Adic Length Scale Hypothesis

Zero energy ontology classically

In TGD inspired cosmology [K93] the embeddings of Robertson-Walker cosmologies are vacuum extremals. Same applies to the embeddings of Reissner-Nordström solution [K114] and in practice to all solutions of Einstein's equations imbeddable as extremals of Kähler action. Since four-momentum currents define a collection of vector fields rather than a tensor in TGD, both positive and negative signs for energy corresponding to two possible assignments of the arrow of the geometric time to a given space-time surface are possible. This leads to the view that all physical states have vanishing net energy classically and that physically acceptable universes are creatable from vacuum.

The result is highly desirable since one can avoid unpleasant questions such as "What are the net values of conserved quantities like rest mass, baryon number, lepton number, and electric charge for the entire universe?", "What were the initial conditions in the big bang?", "If only single solution of field equations is selected, isn't the notion of physical theory meaningless since in principle it is not possible to compare solutions of the theory?". This picture fits also nicely with the view that entire universe understood as quantum counterpart 4-D space-time is recreated in each quantum jump and allows to understand evolution as a process of continual re-creation.

Zero energy ontology at quantum level

Also the construction of S-matrix [K28] leads to the conclusion that all physical states possess vanishing conserved quantum numbers. Furthermore, the entanglement coefficients between positive and negative energy components of the state define an M-matrix which can be seen as a "complex" square root of density matrix decomposable to a square root of diagonal positive definite density matrix and a unitary S-matrix. S-matrix thus becomes a property of the zero energy state and physical states code by their structure what is usually identified as quantum dynamics. The square root of the density matrix means taking square root of thermodynamics which thus becomes genuine part of quantum theory with thermodynamical ensembles realized at single particle level rather than being a useful fiction of theoretician. Also the transitions between zero energy states are possible and described by U matrix which would have natural identification as characterized of intentional action.

At space-time level this would mean that positive energy component and negative energy component are at a temporal distance characterized by an appropriate p-adic time scale and the integer characterizing the value of Planck constant for the state in question. The scale in question would also characterize the geometric duration of quantum jump and the size scale of space-time region contributing to the contents of conscious experience. The interpretation in terms of a mini bang followed by a mini crunch suggests itself also.

How do p-adic coupling constant evolution and p-adic length scale hypothesis emerge from zero energy ontology?

In zero energy ontology zero energy states have as embedding space correlates causal diamonds for which the distance between the tips of the intersecting future and past directed light-cones comes as integer multiples of a fundamental time scale: $T_n = n \times T_0$. p-Adic length scale hypothesis allows to consider a stronger hypothesis $T_n = 2^n T_0$ and its generalization a slightly more general hypothesis $T_n = p^n T_0$, p prime. It however seems that these scales are dynamically favored but that also other scales are possible.

Could the coupling constant evolution in powers of 2 implying time scale hierarchy $T_n = 2^n T_0$ induce p-adic coupling constant evolution and explain why p-adic length scales correspond to $L_p \propto \sqrt{p}R$, $p \simeq 2^k$, R CP_2 length scale? This looks attractive but there is a problem. p-Adic length scales come as powers of $\sqrt{2}$ rather than 2 and the strongly favored values of k are primes and thus odd so that $n = k/2$ would be half odd integer. This problem can be solved.

1. The observation that the distance traveled by a Brownian particle during time t satisfies $r^2 = Dt$ suggests a solution to the problem. p-Adic thermodynamics applies because the partonic 3-surfaces X^2 are as 2-D dynamical systems random apart from light-likeness of their orbit. For CP_2 type vacuum extremals the situation reduces to that for a one-dimensional random light-like curve in M^4. The orbits of Brownian particle would now correspond to light-like geodesics γ_3 at X^3. The projection of γ_3 to a time=constant section $X^2 \subset X^3$ would define the 2-D path γ_2 of the Brownian particle. The M^4 distance r between the end points of γ_2 would be given $r^2 = Dt$. The favored values of t would correspond to $T_n = 2^n T_0$ (the full light-like geodesic). p-Adic length scales would result as $L^2(k) = DT(k) = D2^kT_0$ for $D = R^2/T_0$. Since only CP_2 scale is available as a fundamental scale, one would have $T_0 = R$ and $D = R$ and $L^2(k) = T(k)R$.

2. p-Adic primes near powers of 2 would be in preferred position. p-Adic time scale would not relate to the p-adic length scale via $T_p = L_p/c$ as assumed implicitly earlier but via $T_p = L_p^2/R_0 = \sqrt{p}L_p$, which corresponds to secondary p-adic length scale. For instance, in the case of electron with $p = M_{127}$ one would have $T_{127} = .1$ second which defines a fundamental biological rhythm. Neutrinos with mass around.1 eV would correspond to $L_e(169) \simeq 5$ μm (size of a small cell) and $T(169) \simeq 1. \times 10^4$ years. A deep connection between elementary particle physics and biology becomes highly suggestive.

3. In the proposed picture the p-adic prime $p \simeq 2^k$ would characterize the thermodynamics of the random motion of light-like geodesics of X^3 so that p-adic prime p would indeed be an inherent property of X^3. For $T_p = pT_0$ the above argument is not enough for p-adic length scale hypothesis and p-adic length scale hypothesis might be seen as an outcome of a process analogous to natural selection. Resonance like effect favoring octaves of a fundamental frequency might be in question. In this case, p would a property of CD and all light-like 3-surfaces inside it and also that corresponding sector of WCW .

12.2.4 How To Fuse P-Adic And Real Physics?

Generalization of number concept and fusion of real and p-adic physics

The unification of real physics of material work and p-adic physics of cognition and intentionality leads to the generalization of the notion of number field. Reals and various p-adic number fields are glued along their common rationals (and common algebraic numbers too) to form a fractal book like structure. Allowing all possible finite-dimensional extensions of p-adic numbers brings additional pages to this "Big Book".

This generalization leads to a generalization of the notion of manifold as a collection of a real manifold and its p-adic variants glued together along common rationals (see **Fig.** `http://tgdtheory.fi/appfigures/book.jpg` or bf Fig. **??** in the appendix of this book). The precise formulation involves of course several technical problems. For instance, should one glue along common algebraic numbers and Should one glue along common transcendentals such as e^p? Are algebraic extensions of p-adic number fields glued together along the algebraics too?

This notion of manifold implies a generalization of the notion of embedding space. p-Adic transcendentals can be regarded as infinite numbers in the real sense and thus most points of the p-adic space-time sheets would be at infinite distance and real and p-adic space-time sheets would intersect in a discrete set consisting of rational points. This view in which cognition would be literally cosmic phenomena is in a sharp contrast with the often held belief that p-adic topology emerges below Planck length scale.

What number theoretical universality might mean?

Number theoretic universality has been one of the basic guide lines in the construction of quantum TGD. There are two forms of the principle.

1. The strong form of number theoretical universality states that physics for any system should effectively reduce to a physics in algebraic extension of rational numbers at the level of M-matrix so that an interpretation in both real and p-adic sense (allowing a suitable algebraic extension of p-adics) is possible. One can however worry whether this principle only means that physics is algebraic so that there would be no need to talk about real and p-adic physics at the level of M-matrix elements. It is not possible to get rid of real and p-adic numbers at the level of classical physics since calculus is a prerequisite for the basic variational principles used to formulate the theory. For this option the possibility of completion is what poses conditions on M-matrix.

2. The weak form of principle requires only that both real and p-adic variants of physics make sense and that the intersection of these physics consist of physics associated with various algebraic extensions of rational numbers. In this rational physics would be like rational numbers allowing infinite number of algebraic extensions and real numbers and p-adic number fields as its completions. Real and p-adic physics would be completions of rational physics. In this framework criticality with respect to phase transitions changing number field becomes a viable concept. This form of principle allows also purely p-adic phenomena such as p-adic pseudo non-determinism assigned to imagination and cognition. Genuinely p-adic physics does not however allow definition of notions like conserved quantities since the notion of definite integral is lacking and only the purely local form of real physics allows p-adic counterpart.

Experience has taught that it is better to avoid too strong statements and perhaps the weak form of the principle is enough. It is however clear that number theoretical criticality could provide important insights to quantum TGD. p-Adic thermodynamics is excellent example of this. In consciousness theory the transitions transforming intentions to actions and actions to cognitions would be key applications. Needless to say, zero energy ontology is absolutely essential: otherwise this kind of transitions would not make sense. In the original version of this chapter number theoretical universality was identified as number theoretical criticality and this leads to so strong conditions that they might not be possible to satisfy.

p-Adicization by algebraic continuation

The basic challenges of the p-adicization program are following.

1. The first problem -the conceptual one- is the identification of preferred coordinates in which functions are algebraic and for which algebraic values of coordinates are in preferred position. This problem is encountered both at the level of space-time, embedding space, and WCW . Here the group theoretical considerations play decisive role and the selection of preferred coordinates relates closely to the selection of quantization axes. This selection has direct physical correlates at the level of embedding space and the hierarchy of Planck constants has interpretation as a correlate for the selection of quantization axes [K40].

   Algebraization does not necessarily mean discretization at space-time level: for instance, the coordinates characterizing partonic 2-surface can be algebraic so that algebraic point of the WCW results and surface is not discretized. If this kind of function spaces are finite-dimensional, it is possible to fix X^2 completely data for a finite number of points only.

2. Local physics generalizes as such to p-adic context (field equations, etc...). The basic stumbling block of this program is integration already at space-time (Kähler action etc..). The problem becomes really horrible looking at WCW level (functional integral). Algebraic continuation could allow to circumvent this difficulty. Needless to say, the requirement that the continuation exists must pose immensely tight constraints on the physics. For instance, at WCW level radiative corrections to the functional integral should vanish and the resulting perturbation theory using propagators and vertices could make sense p-adically.

One general idea which results as an outcome of the generalized notion of number is the idea of a universal function continuable from a function mapping rationals to rationals or to a finite extension of rationals to a function in any number field. This algebraic continuation is analogous to the analytical continuation of a real analytic function to the complex plane.

1. Rational functions with rational coefficients are obviously functions satisfying this constraint. Algebraic functions with rational coefficients satisfy this requirement if appropriate finite-dimensional algebraic extensions of p-adic numbers are allowed. Exponent function is such a function.

2. For instance, residue calculus essential in the construction of N-point functions of conformal field theory might be generalized so that the value of an integral along the real axis could be calculated by continuing it instead of the complex plane to any number field via its values in the subset of rational numbers forming the rim of the book like structure having number fields as its pages. If the poles of the continued function in the finitely extended number field allow interpretation as real numbers it might be possible to generalize the residue formula. One can also imagine of extending residue calculus to any algebraic extension. An interesting situation arises when the poles correspond to extended p-adic rationals common to different pages of the "Big book". Could this mean that the integral could be calculated at any page having the pole common. In particular, could a p-adic residue integral be calculated in the ordinary complex plane by utilizing the fact that in this case numerical approach makes sense.

3. Algebraic continuation is the basic tool of p-adicization program. Entire physics of the TGD Universe should be algebraically continuable to various number fields. Real number based physics would define the physics of matter and p-adic physics would describe correlates of cognition.

4. For instance, the idea that number theoretically critical partonic 2-surfaces are expressible in terms of rational functions with rational or algebraic coefficients so that also p-adic variants of these surfaces make sense, is very attractive.

5. Finite sums and products respect algebraic number property and the condition of finiteness is coded naturally by the notion of finite measurement resolution in terms of the notion of (number theoretic) braid. This simplifies dramatically the algebraic continuation since WCW reduces to a finite-dimensional space and the space of WCW spinor fields reduces to finite-dimensional function space.

The real WCW can well contain sectors for which p-adicization does not make sense. For instance, if the exponent of Kähler function and Kähler are not expressible in terms of algebraic functions with rational or at most algebraic functions or more general functions making sense p-adically, the continuation is not possible. p-Adic non-determinism in p-adic sectors makes also impossible the continuation to real sector. All this is consistent with vision about rational and algebraic physics as as analog of rational and algebraic numbers allowing completion to various continuous number fields.

Due to the fact that real and p-adic topologies are fundamentally different, ultraviolet and infrared cutoffs in the set of rationals are unavoidable notions and correspond to a hierarchy of different physical phases on one hand and different levels of cognition on the other hand. For instance, most points p-adic space-time sheets reside at infinity in real sense and p-adically infinitesimal is infinite in real sense. Two types of cutoffs are predictedp-adic length scale cutoff and a cutoff due to phase resolution related to the hierarchy of Planck constants. Zero energy ontology provides natural realization for the p-adic length scale cutoff. The latter cutoff seems to correspond naturally to the hierarchy of algebraic extensions of p-adic numbers and quantum phases $exp(i2\pi/n)$, $n \geq 3$, coming as roots of unity and defining extensions of rationals and p-adics allowing to define p-adically sensible trigonometric functions These phases relate closely to the hierarchy of quantum groups, braid groups, and II_1 factors of von Neumann algebra.

12.2.5 P-Adic Physics And Consciousness

The original vision was that p-adic physics is physics of cognition. It has however turned out that it is only physics of cognition and that the attempt to describe intentional action in terms of p-adic physics leads to mathematical difficulties and is also un-necessary. This view is also in nice concordance with the existing mathematics and adeles provide a natural approach to the unification of reals and p-adics.

p-Adic physics and cognition

p-Adic physics as physics of cognition provides one of the key elements of TGD inspired theory of consciousness. At the fundamental level light-like 3-surfaces are basic dynamical objects in TGD Universe and have interpretation as orbits of partonic 2-surfaces. The generalization of the notion of number concept by fusing real numbers and various p-adic numbers to a more general structure makes possible to assign to real parton a p-adic prime p and corresponding p-adic partonic 3-surface obeying same algebraic equations. The almost topological QFT property of quantum TGD is an essential prerequisite for this. The intersection of real and p-adic 3-surfaces would consists of a discrete set of points with coordinates which are algebraic numbers. p-Adic partons would relate to both intentionality and cognition.

Real fermion and its p-adic counterpart forming a pair would represent matter and its cognitive representation being analogous to a fermion-hole pair resulting when fermion is kicked out from Dirac sea. The larger the number of points in the intersection of real and p-adic surfaces, the better the resolution of the cognitive representation would be. This would explain why cognitive representations in the real world are always discrete (discreteness of numerical calculations represent the basic example about this fundamental limitation).

All transcendental p-adic integers are infinite as real numbers and one can say that most points of p-adic space-time sheets are at spatial and temporal infinity in the real sense so that intentionality and cognition would be literally cosmic phenomena. If the intersection of real and p-adic space-time sheet contains large number of points, the continuity and smoothness of p-adic physics should directly reflect itself as long range correlations of real physics realized as p-adic fractality. It would be possible to measure the correlates of cognition and in the framework of zero energy ontology [K28] the success of p-adic mass calculations can be seen as a direct evidence for the role of intentionality and cognition even at elementary particle level: all matter would be basically created by intentional action as zero energy states.

Generalization of the notion of information

TGD inspired theory of consciousness, in particular the formulation of Negentropy Maximization Principle (NMP) in p-adic context, has forced to rethink the notion of the information concept. In TGD state preparation process is realized as a sequence of self measurements. Each self measurement means a decomposition of the sub-system involved to two unentangled parts. The decomposition is fixed highly uniquely from the requirement that the reduction of the entanglement entropy is maximal.

The additional assumption is that bound state entanglement is stable against self measurement. This assumption is somewhat ad hoc and it would be nice to get rid of it. The only manner to achieve this seems to be a generalized definition of entanglement entropy allowing to assign a negative value of entanglement entropy to the bound state entanglement, so that bound state entanglement would actually carry information, in fact conscious information (experience of understanding). This would be very natural since macro-temporal quantum coherence corresponds to a generation of bound state entanglement, and is indeed crucial for ability to have long lasting non-entropic mental images.

The generalization of the notion of number concept leads immediately to the basic problem. How to generalize the notion of entanglement entropy that it makes sense for a genuinely p-adic entanglement? What about the number-theoretically universal entanglement with entanglement probabilities, which correspond to finite extension of rational numbers? One can also ask whether the generalized notion of information could make sense at the level of the space-time as suggested by quantum-classical correspondence.

In the real context Shannon entropy is defined for an ensemble with probabilities p_n as

$$S = -\sum_n p_n log(p_n) \ . \tag{12.2.1}$$

As far as theory of consciousness is considered, the basic problem is that Shannon entropy is always non-negative so that as such it does not define a genuine information measure. One could define information as a change of Shannon entropy and this definition is indeed attractive in the sense that quantum jump is the basic element of conscious experience and involves a change. One can however argue that the mere ability to transfer entropy to environment (say by aggressive behavior) is not all that is involved with conscious information, and even less so with the experience of understanding or moment of eureka. One should somehow generalize the Shannon entropy without losing the fundamental additivity property.

p-Adic entropies

The key observation is that in the p-adic context the logarithm function $log(x)$ appearing in the Shannon entropy is not defined if the argument of logarithm has p-adic norm different from 1. Situation changes if one uses an extension of p-adic numbers containing $log(p)$: the conjecture is that this extension is finite-dimensional. One might however argue that Shannon entropy should be well defined even without the extension.

p-Adic thermodynamics inspires a way to achieve this. One can replace $log(x)$ with the logarithm $log_p(|x|_p)$ of the p-adic norm of x, where log_p denotes p-based logarithm. This logarithm is integer valued ($log_p(p^n) = n$), and is interpreted as a p-adic integer. The resulting p-adic entropy

$$\begin{aligned} S_p &= \sum_n p_n k(p_n) \ , \\ k(p_n) &= -log_p(|p_n|) \ . \end{aligned} \tag{12.2.2}$$

is additive: that is the entropy for two non-interacting systems is the sum of the entropies of composites. Note that this definition differs from Shannon's entropy by the factor $log(p)$. This entropy vanishes identically in the case that the p-adic norms of the probabilities are equal to one. This means that it is possible to have non-entropic entanglement for this entropy.

One can consider a modification of S_p using p-adic logarithm if the extension of the p-adic numbers contains $log(p)$. In this case the entropy is formally identical with the Shannon entropy:

$$S_p = -\sum_n p_n log(p_n) = -\sum_n p_n \left[-k(p_n) log(p) + p^{k_n} log(p_n/p^{k_n}\right] \ . \tag{12.2.3}$$

It seems that this entropy cannot vanish.

One must map the p-adic value entropy to a real number and here canonical identification can be used:

$$\begin{aligned} S_{p,R} &= (S_p)_R \times log(p)) \ , \\ (\sum_n x_n p^n)_R &= \sum_n x_n p^{-n} \ . \end{aligned} \tag{12.2.4}$$

The real counterpart of the p-adic entropy is non-negative.

Number theoretic entropies and bound states

In the case that the probabilities are rational or belong to a finite-dimensional extension of rationals, it is possible to regard them as real numbers or p-adic numbers in some extension of p-adic numbers for any p. The visions that rationals and their finite extensions correspond to islands of order in the seas of chaos of real and p-adic transcendentals suggests that states having entanglement coefficients in finite-dimensional extensions of rational numbers are somehow very special. This is indeed the case. The p-adic entropy entropy $S_p = -\sum_n p_n log_p(|p_n|)log(p)$ can be interpreted in this case as an ordinary rational number in an extension containing $log(p)$.

What makes this entropy so interesting is that it can have also negative values in which case the interpretation as an information measure is natural. In the real context one can fix the value of the value of the prime p by requiring that S_p is maximally negative, so that the information content of the ensemble could be defined as

$$I \equiv Max\{-S_p, \ \ p \text{ prime}\} \ . \tag{12.2.5}$$

This information measure is positive when the entanglement probabilities belong to a finite-dimensional extension of rational numbers. Thus kind of entanglement is stable against NMP, and has a natural interpretation as bound state entanglement. The prediction would be that the bound states of real systems form a number theoretical hierarchy according to the prime $panddimension$ of algebraic extension characterizing the entanglement.

Number theoretically state function reduction and state preparation could be seen as information generating processes projecting the physical states from either real or p-adic sectors of the state space to their intersection. Later an argument that these processes have a purely number theoretical interpretation will be developed based on the generalized notion of unitarity allowing the U-matrix to have matrix elements between the sectors of the state space corresponding to different number fields.

Does living matter reside in the intersection of real and p-adic worlds?

Number theoretic entanglement entropies make sense only if entanglement probabilities are real or algebraic numbers in the extension of p-adic numbers considered. This is implied by number theoretic universality in the intersection of real and p-adic variants of the embedding space which at QFT limit of TGD correspond to discrete points of partonic 2-surfaces carrying elementary particle numbers. Their motion along light-like 3-surfaces gives rise to number theoretic braids [K28].

At WCW level the intersection of real and p-adic worlds would correspond to a more abstract intersection with the counterpart of rationals identified as light-like 3-surfaces represented by rational functions with rational coefficients identifiable as common to real and p-adic worlds. State function reduction to the intersection of p-adic and real worlds would induce also the rationality (or algebraic number property) of the entanglement probabilities since they must make sense both p-adically and in the real sense. One might say that the enlightenment means living in both real and p-adic world simultaneously.

One manner to understand the special role of rationals and algebraics relies on the observation that rationals represent islands of order in the sea of chaos defined by reals since their pinary expansion is predictable and analogous to a periodic orbit of a dynamical system whereas for a generic real number there is no manner to predict the pinary expansion.

The phase transitions transforming p-adic space-time sheets to real ones could be understood as a tunnelling through the intersection of the p-adic and real worlds: here zero energy ontology is absolutely essential in order to avoid the problems caused by the impossibility to compare directly real and p-adic quantum numbers and by the non-existence of p-adic conserved charges caused by the lack of definite integral (field equations however make sense). This would provide one candidate for the formation of cognitive representation on one hand and for the transformation of intention to action on the other hand. Only living matter could carry negentropic entanglement and evolution would take place in the intersection of p-adic and real worlds. This has rather far reaching implications also for understanding the evolution of consciousness if one accepts Negentropy Maximization Principle as the basic variational principle of consciousness. These implications are discussed in [K87].

12.2.6 P-Adic Length Scale Hypothesis And Biosystems

In the following a brief summary about biologically relevant p-adic length scales is given.

p-Adic coupling constant evolution

Could the time scale hierarchy $T_n = 2^n T_0$ defining hierarchy of measurement resolutions in time variable induce p-adic coupling constant evolution and explain why p-adic length scales correspond to $L_p \propto \sqrt{p}R$, $p \simeq 2^k$, R CP_2 length scale? This looks attractive but there is a problem. p-Adic length scales come as powers of $\sqrt{2}$ rather than 2 and the strongly favored values of k are primes and thus odd so that $n = k/2$ would be half odd integer. This problem can be solved.

1. The observation that the distance traveled by a Brownian particle during time t satisfies $r^2 = Dt$ suggests a solution to the problem. p-Adic thermodynamics applies because the partonic 3-surfaces X^2 are as 2-D dynamical systems random apart from light-likeness of their orbit. For CP_2 type vacuum extremals the situation reduces to that for a one-dimensional random light-like curve in M^4. The orbits of Brownian particle would now correspond to light-like geodesics γ_3 at X^3. The projection of γ_3 to a time=constant section $X^2 \subset X^3$ would define the 2-D path γ_2 of the Brownian particle. The M^4 distance r between the end points of γ_2 would be given $r^2 = Dt$. The favored values of t would correspond to $T_n = 2^n T_0$ (the full light-like geodesic). p-Adic length scales would result as $L^2(k) = DT(k) = D2^k T_0$ for $D = R^2/T_0$. Since only CP_2 scale is available as a fundamental scale, one would have $T_0 = R$ and $D = R$ and $L^2(k) = T(k)R$.

2. p-Adic primes near powers of 2 would be in preferred position. p-Adic time scale would not relate to the p-adic length scale via $T_p = L_p/c$ as assumed implicitly earlier but via $T_p = L_p^2/R_0 = \sqrt{p}L_p$, which corresponds to secondary p-adic length scale. For instance, in the case of electron with $p = M_{127}$ one would have $T_{127} = .1$ second which defines a fundamental biological rhythm. Neutrinos with mass around.1 eV would correspond to $L_e(169) \simeq 5$ μm (size of a small cell) and $T(169) \simeq 1. \times 10^4$ years. A deep connection between elementary particle physics and biology becomes highly suggestive.

3. In the proposed picture the p-adic prime $p \simeq 2^k$ would characterize the thermodynamics of the random motion of light-like geodesics of X^3 so that p-adic prime p would indeed be an inherent property of X^3.

4. The fundamental role of 2-adicity suggests that the fundamental coupling constant evolution and p-adic mass calculations could be formulated also in terms of 2-adic thermodynamics. With a suitable definition of the canonical identification used to map 2-adic mass squared values to real numbers this is possible, and the differences between 2-adic and p-adic thermodynamics are extremely small for large values of for $p \simeq 2^k$. 2-adic temperature must be chosen to be $T_2 = 1/k$ whereas p-adic temperature is $T_p = 1$ for fermions. If the canonical identification is defined as

$$\sum_{n\geq 0} b_n 2^n \rightarrow \sum_{m\geq 1} 2^{-m+1} \sum_{(k-1)m\leq n<km} b_n 2^n \ .$$

It maps all 2-adic integers $n < 2^k$ to themselves and the predictions are essentially same as for p-adic thermodynamics. For large values of $p \simeq 2^k$ 2-adic real thermodynamics with $T_R = 1/k$ gives essentially the same results as the 2-adic one in the lowest order so that the interpretation in terms of effective 2-adic/p-adic topology is possible.

Biologically relevant primary p-adic length scales

The identification of p-adic length scales above electron length scale involves a systematic error in all writings before 2004. This deserves some comments.

1. The wrong identification was $L(151) \simeq 10$ nm implying wrong identification of other scales above $L(127)$ since I have calculated them by scaling $L(151)$ by an appropriate power of two.

k	127	131	137	139	149
$L_e(k)/10^{-10}m$	.025	.1	.8	1.6	50
k	151	157	163	167	169
$L_e(k)/10^{-8}m$	1	8	64	256	512
k	173	179	181	191	193
$L_e(k)/10^{-4}m$	.2	1.6	3.2	100	200
k	197	199	211	223	227
$L_e(k)/m$	.08	.16	10	640	2560

Table 12.1: Primary p-adic length scales $L_e(k) = \sqrt{5}L_(k) = 2^{k-151}L_e(151)$, $p \simeq 2^k$, k prime, possibly relevant to biophysics. The last 3 scales are included in order to show that twin pairs are very frequent in the biologically interesting range of length scales. The length scale $L_e(151)$ is take to be thickness of cell scale, which is 10^{-8} meters in good approximation.

What I have denoted by $L(151)$ is actually obtained by scaling the Compton length $L_e(127) = \hbar/m_e$ by $2^{(151-127)/2}$ and therefore electrons Compton scale if it would correspond to $k = 151$. Since the mass of electron from p-adic mass calculations is given by $m_e = \sqrt{5+X}\hbar/L(127)$, the correct identification of $L(151)$ would be

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

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

2. This mistake has no fatal consequences for TGD inspired quantum biology. Its detection however provides a further support for the speculated central role of electron in living matter. Since the scales obtained by scaling the electron Compton scale seem to be important biologically (scaled up Comton scale $\sqrt{5}L(151)$ corresponds to cell membrane thickness), the conclusion is that electrons - or perhaps their Cooper pairs - play a fundamental role in living matter. The correct value of $L(151)$ is $L(151) = 4.5$ nm, which is slightly below the p-adic length scale $L_e(149) = 5$ nm assigned with the lipid layer of cell membrane.

3. I have also assigned to electron the time scale $T = .1$ seconds defining a fundamental biorhythm as a secondary p-adic time scale $T_2(127) = \sqrt{M_{127}}T(127)$. The correct assignment of $T = .1$ seconds is as the secondary Compton time $T_{2,e}(127) = \sqrt{M_{127}}T_e(127)$ of electron: secondary p-adic time scale is $T_2(127) = \sqrt{M_{127}}T(127)$ and corresponds to $T_{2,e}(127)/\sqrt{5} = .045$ seconds and to $f(127) = 22.4$ Hz.

Table 12.1 lists the p-adic length scales L_p, p near prime power of 2, which might be interesting as far as biosystems are considered.

Some overall scaling factor r of order one is present in the definition of the length scale and it is interesting to look whether with a suitable choice of r it is possible to identify p-adic length scales as biologically important length scales. The requirement that p-adically scaled up electron Compton scale $L_e(151) \simeq \sqrt{5}L_e(151)$ corresponds to the thickness of the cell membrane about 10^{-8} meters gives $r \simeq 1.2$.

The study of the table supports the idea that p-adic length scale hypothesis might have explanatory power in biology. What is remarkable is the frequent occurrence of twin length scales related by a factor 2 in the range of biologically interesting p-adic length scales: only 3 of 15 primes in the range do not belong to a twin pair! The fact that these length scales seem to correspond to biologically interesting length scales suggests that twins might be related to replication phenomenon and to the possible 2-adicity in biology: for a given twin pair the smaller length scale would define basic 2-adic length scale. In the following the scales denoted by $\hat{L}_e(k)$ are related by a factor $r = 1.2$ to the length scales $L_e(k)$ appearing in **Table 12.1**

1. $\hat{L}_e(137) \simeq 7.84E-11\ m$, $\hat{L}_e(139) \simeq 1.57E-10m$ form a twin pair. This length scales might be associated with atoms and small molecules.

2. The secondary scale $\hat{L}_e(71,2) \simeq .44$ nm corresponds to the thickness of the DNA strand which is about.5 nm. Both DNA strand and double helix must correspond to this length scale. The secondary p-adic length scale $L_e(\hat{73},2) \simeq 1.77\ nm$ is longer than the thickness of DNA double strand which is roughly 1.1 nm. Whether one could interpret this length scale as that associated with DNA double strand remains an open question. alpha helix, the basic building block of proteins provides evidence for has radius 1.81 $nm \sim \hat{L}_e(139)$ and the height of single step in the helix is .544 nm.

3. $\hat{L}_e(149) \simeq .5.0\ nm$ and $\hat{L}_e(151) \simeq 10.0\ nm$ form also a twin pair. The thickness of cell membrane of order $10^{-8}\ m \sim \hat{L}_e(151)$. Cell membrane consists of two separate membranes and the thickness of single membrane therefore corresponds to $\hat{L}_e(149)$. Microtubules, which are basic structural units of the cytoskeleton, are hollow cylindrical surfaces having thickness $d \sim 11\ nm$, which is not too far from the length scale $\hat{L}_e(151)$. It has been suggested that microtubules might play key role in the understanding of biosystem as macroscopic quantum system [J71, J8].

4. If neutrinos have masses of order one eV as suggested by recent experiments then the primary condensation level of neutrinos could correspond to $k_Z = 167$ or $k_Z = 13^2 = 169$ and would be the level at which nuclei feed their Z^0 gauge charges. This level is many particle quantum system in p-adic sense and p-adic effects are expected to important at this condensation level. Chirality selection should take place via the breaking of neutrino superconductivity at this level and involve the generation of Z^0 magnetic fields at some level $k < k_Z$, too. $k = 151$ is a good candidate for the level in question.

5. In the previous version of this chapter it was stated that $\hat{L}_e(167) = 2.73\ \mu m$, $\hat{L}_e(169 = 13^2) = 5.49\ \mu m$ form a twin pair and correspond to typical length scales associated with cellular structures. Neutrino mass calculations give best predictions for $k = 169$ and this suggests that the generalization of "k = prime" to "k = power of prime" should be considered: generalization would allow also $k = 169$ as basic length scale. Also blackhole elementary particle analogy suggests the generalization of the length scale hypothesis. Furthermore, only $k = 169$ would appear as a new length scale between electron length scale and astrophysical length scales ($k = 3^5, 2^8, 17^2$)! This suggests that the length scales $L_e(167)$ and $L_e(169)$ might form effective twin pair. That this could be the case is suggested by the fact that so called epithelial sheets appearing in skin, glands, etc., consisting of two layers of cells play in biosystems same role as cell membranes and are generally regarded as a step of bioevolution analogous to the formation of cell membrane.

6. $\hat{L}_e(173) = 2.20 \cdot 10^{-5}\ m$ might correspond to a size of some basic cellular structure (A structure consisting of 64 cell layers?). $\hat{L}_e(179) = 1.75 \cdot 10^{-5}\ m$ and $\hat{L}_e(181) = 3.52 \cdot 10^{-4}\ m$ form a twin pair. Later it will be found that the pair $k = 179, 181$ might correspond to basic structures associated with cortex.

7. Length scales $\hat{L}_e(191) = 1.12\ cm, \hat{L}_e(193) = 2.24\ cm$ and $\hat{L}_e(197) = 9.0\ cm$. $\hat{L}_e(199) = 18.0\ cm$ are again twins.

Secondary p-adic time scales and biology

The basic implication of zero energy ontology is the formula $T_2(k) = T(k) \simeq 2^{k/2}L_e(k)/c = L_e(2,k)/c$ for the secondary p-adic time scale for $p \simeq 2^k$. This would be the analog of $E = hf$ in quantum mechanics and together hierarchy of Planck constants would imply a direct connection between elementary particle physics and macroscopic physics. Especially important this connection would be in macroscopic quantum systems, say for Bose Einstein condensates of Cooper pairs, whose signature the rhythms with $T(k)$ as period would be. The presence of this kind of rhythms might even allow to deduce the existence of Bose-Einstein condensates of hitherto unknown particles.

Unfortunately, the mistake in the identification of the p-adic length scales above electron scale forces to modify the definition of $T(k)$ by introducing a $\sqrt{5+X}$ factor so that it becomes the secondary Compton time scale of electron in the p-adic length scale considered. Writing this explicitly, one has $T_e(k) \equiv T_{2,e}(k) = 2^{k-127}T_{2,e}(127) \equiv 2^{k-127}T_e(127)$. Apologies for a loose notation replacing subscript "2, e" with "e".

1. For electron secondary Compton time equal to $T_e(k) = .1$ seconds defines the fundamental $f_e = 10$ Hz bio-rhythm appearing as a peak frequency in alpha band. This could be seen as a direct evidence for a Bose-Einstein condensate of Cooper pairs of high T_c super-conductivity. That transition to "creative" states of mind involving transition to resonance in alpha band might be seen as evidence for formation of large BE condensates of electron Cooper pairs.

2. TGD based model for atomic nucleus [L3] predicts that nucleons are connected by flux tubes having at their ends light quarks and anti-quarks with masses not too far from electron mass. The corresponding p-adic frequencies $f_q = 2^k f_e$ could serve as a biological signature of exotic quarks connecting nucleons to nuclear strings. $k_q = 118$ suggested by nuclear string model would give $f_q = 2^{18} f_e = 26.2$ Hz. Schumann resonances are around 7.8, 14.3, 20.8, 27.3 and 33.8 Hz and f_q is not too far from 27.3 Hz Schumann resonance and the cyclotron frequency $f_c(^{11}B^+) = 27.3$ Hz for $B = .2$ Gauss explaining the effects of ELF em fields on vertebrate brain.

3. For a given $T_e(k)$ the harmonics of the fundamental frequency $f = 1/T(k)$ are predicted as special time scales. Also resonance like phenomena might present. In the case of cyclotron frequencies they would favor values of magnetic field for which the resonance condition is achieved. The magnetic field which in case of electron gives cyclotron frequency equal to 10 Hz is $B_e \simeq 3.03$ nT. For ion with charge Z and mass number A the magnetic field would be $B_I = \frac{A}{Z}(m_p/m_e)B_e$. The $B = .2$ Gauss magnetic field explaining the findings about effects of ELF em fields on vertebrate brain is near to B_I for ions with f_c alpha band. Hence the value of B could be understood in terms of resonance with electronic B-E condensate.

4. The hierarchy of Planck constants predicts additional time scales $T_e(k)$. The prediction depends on the strength of the additional assumptions made. One could have scales of form $nT(k)$. Integers n could correspond to ruler and compass integers expressible as products of first powers of Fermat primes and power of 2. There are only four known Fermat primes so that one has $n = 2^n \prod_i F_i,\ F_i \in \{3, 5, 17, 257, 2^{16} + 1\}$. In the first approximation only 3- and 5- and 17-multiples of 2-adic length scales would result besides 2-adic length scales.

5. Mersenne primes are expected to define the most important fundamental p-adic time scales. The list of real and Gaussian (complex) Mersennes M_n possibly relevant for biology is given by n=89, 107, 113*, 127, 151*, 157*, 163*, 167* ("*" tells that Gaussian Mersenne is in question).

$$\begin{array}{lllll}
n & 89 & 107 & 113 & 127 \\
f_e/Hz & 2.7\times 10^{12} & 1.0\times 10^{7} & 1.6\times 10^{5} & 10 \\
n & 151 & 157 & 163 & 167 \\
T & 19.4\ d & 3.40\ y & 218.0\ y & 3.49\times 10^{3}\ y
\end{array} \quad (12.2.6)$$

12.3 P-Adic Ultra-Metricy And Biosystems

Ultra-metricity is what distinguishes p-adic notion of distance and topology from the real one and makes the latter coarser than the real topology.

12.3.1 Spin Glasses And Ultra-Metricity

Spin glasses [B21, B28, B10] are spin systems with the property that the couplings J_{kl} between neighboring spins σ_k and σ_l are random variables although the characteristic scale of time variation of J_{kl} is very long as compared to the corresponding time scale associated with the dynamics of the spins. The characteristic property of spin glasses is their infinite ground state degeneracy. More precisely, the dynamics of the spin glasses is non-ergodic and there is infinite number of pure states, which correspond to the local minima of free energy. For the purposes of comparison it should be recalled that for ferromagnet above critical temperature only one pure state exists and below the critical temperature there are two pure states corresponding to two possible directions of magnetization.

The space of pure states possesses a very general property called ultra-metricity, which means that one can define in this space distance function $d(x,y)$ with the property

$$d(x,z) \quad \leq \quad max\{d(x,y),d(y,z)\} \ . \tag{12.3.1}$$

The properties of the distance function make it possible to decompose the space 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

$$d(x,y) \quad \leq \quad D \ . \tag{12.3.2}$$

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.

These properties of ultra-metric spaces suggest several biological applications.

1. Parisi [B21] has suggested that ultra-metricity might be used in taxonomy. Individuals of various species correspond to points of the ultra-metric space and ultra-metric distance gives mathematical description for the classification criterion: in practice ultra-metric distance might correspond to some genetic measure for the difference between individuals.

2. The representation of biological information seems to take place using a hierarchy of categories. Lowest and most important categories are very rough (friend/ enemy?, black/white?, etc...). Higher levels correspond more refined classifications (what kind of enemy?, does enemy move or not?, ...). This kind of representation has obvious value in the struggle for survival. The hypothesis that biosystems save information into variables, which define points of ultra-metric space, leads automatically to a hierarchical structure of information storage. The simplest model assumes that states of brain or at least memories correspond to free energy minima of a spin glass like statistical system [B28].

3. Statistical models of memory and learning process, which share with spin glasses the property that the minima of free energy form ultra-metric space are proposed [B28], the main idea being that memories correspond to the minima of free energy. Learning takes place in these models via a slow change (slow as compared to the time scale of the dynamics associated with the spin variables) of the field J_{kl} associated with bond connecting k: th and l: th cell.

12.3.2 P-Adic Ultra-Metricity

p-Adic numbers [A8] are a natural candidate for a basic tool in the description of higher dimensional critical systems since the distance function defined by p-adic norm is ultra-metric. The verification of the ultra-metricity is elementary task using the definition of the p-adic norm [A8]

$$|x|_p = |\sum_{k\geq k_0} x_k p^k| = p^{-k_0} \quad . \tag{12.3.3}$$

Since p-adic norm possesses discrete set of values, the values of the parameter D in the classification criterion $|x-y|_p \leq D$ can be chosen to be belong to the set $\{D_k = p^{-k}\}$, k integer. p-Adic numbers belonging to same class have same k: th pinary digit p-adic cutoff

$$\begin{aligned} x &= x_0 + x_1 \ , \\ x_0 &= \sum_{k_1<m<k} x_m p^m \ , \\ x_1 &= \sum_{m\geq k} x_m p^m \ , \end{aligned} \tag{12.3.4}$$

so that the set of classes corresponds to p-adic numbers with cutoff in k: th pinary digit. In this picture the p-adic power expansion of any p-adic observable defines a tree. The levels of the tree correspond to various pinary digits of p-adic number and each branching point gives rise to p branches. In p-adic case one can regard the root of the either as the highest cutoff pinary digit or lowest non-vanishing pinary digit of the p-adic number. In the first case, the tree is infinite: in the latter case the tree is always finite.

For x, y with same p-adic norm (same class) and z with different p-adic norm as x, y (different class) the distance function satisfies the condition

$$\begin{aligned} d_p(x,y) &\leq d_p(x,z) \ \ p>2 \ , \\ d_2(x,y) &< d_2(x,z) \ , \end{aligned} \tag{12.3.5}$$

so that there is important difference between $p = 2$ and $p > 2$ cases. Ultra-metricity (or non-Archimedean property as it is called in p-adic context) holds also true for the algebraic extensions of p-adic numbers with distance defined by the canonical norm [A8].

It has become clear that p-adicity emerges in TGD at the level of space-time topology and that one can identify p-adic space-time regions as cognitive representations of matter regions. Thus p-adic dynamics is predicted to be the dynamics of cognition and thus p-adic ultra-metricity, the exotic features of p-adic probability concept, and non-determinism of p-adic differential equations are predicted to characterize the physics of cognition.

There is however also a second manner how p-adic ultra-metricity might emerge in the description of biological systems. TGD Universe is quantum critical and critical systems [B27] are characterized typically by a large degeneracy of metastable states and resemble in this respect spin glasses. The vacuum degeneracy of the Kähler action defining the Kähler function in the WCW is highly analogous to the ground state degeneracy of the spin glasses in [K46, K16]. One cannot therefore exclude the possibility that p-adicity, in particular, small-p p-adicity for which there is also evidence, could emerge at the level of energy landscape of spin glass. According to the arguments of quantum TGD the reduced WCW CH_{red}, consisting of the maxima of Kähler function as a function of zero modes characterizing the shape, size and induced Kähler fields on 3-surface, can be regarded as a spin glass energy landscape. Hence one can define ultra-metric distance function, and it is possible that this distance function could be regarded as being induced from p-adic norm.

12.3.3 P-Adic Ultra-Metricity And Information Processing In Biosystems

This picture suggest a general model for the information processing in biosystems. Observations made by biosystem correlate with the variables characterizing the possibly conscious knowledge of the system about itself. The p-adic expansions of these variables give intrinsically hierarchical coding of the information associated with the observation. The lowest pinary digit is the most significant pinary digit and gives the roughest description for the observation. Higher pinary digits add details to the observation. The number of pinary digits in the p-adic representation of the observation measures the amount of information associated with it. The time order in which the information is stored or retrieved is from lowest to highest pinary digit. The Slaving Hierarchy associated with the topological condensation might have counterpart at the level of biosystems: this would mean the existence of a hierarchy $p_1 < p_2 < ..p_n < ..$ of p-adic dynamics each with its own characteristic time scale satisfying $T_1 < T_2 < .... < T_n < ...$ and the relationship between two consecutive dynamics is that of master and slave. The higher the level p_n in the p-adic Slaving Hierarchy the higher is the intelligence associated with that level as measured in the number of possible conceptual categories.

A highly nontrivial prediction is that the number of conceptual categories is same at all levels and equal to prime p. This means that $p = 2$ case provides most primitive (but much used!) classification of type black/white. A well known mystery of cognitive science is the so called 7 ± 2 rule [B24]: human mind tends to classify observations into $p = 7$ categories and the classification using more categories than this is difficult. One possibility to test applicability of the p-adic ideas to biosystems is to check whether bio-systems obey small-p p-adic rather than ordinary statistics. The nondeterminism and fractality of biosystems might be in better accordance with p-adic rather than ordinary statistics.

The analogy with spin glass models of learning suggests a microscopic TGD inspired physical model for learning. Short term learning is believed to correspond to slow changes in synaptic connections between neighboring cells. Long term learning probably involves the formation of new contacts between neighoring cells and according to suggestion of [K51] topological storage of information. In TGD inspired model for brain it was suggested that cells correspond to "topological field quanta", 3-surfaces possessing outer boundary and having size of cell One mechanism for the formation of macroscopic quantum systems is as a formation of bonds connecting boundaries of neighbouring "topological field quanta" (now 3-surfaces associated with cells). A possible identification for the counterpart of the spin glass coupling parameter J_{kl} is as Kähler electric interaction energy between neighbouring topological field quanta associated with this kind of bond. Therefore it would be the Kähler electric fluxes through the bonds, which change primarily in the short term learning. This change can be partially nondeterministic process since p-adic dynamics allows partial non-determinism and this nondeterminism is related to freedom to choose the low pinary digits of the dynamical variables arbitrarily.

12.4 P-Adic Non-Determinism And Biosystems

The non-determinism of quantum jump, the classical non-determinism associated with the maximization of Kähler action, and p-adic non-determinism form a trinity of independent non-determinisms. Classical non-determinism of Kähler action can be assigned with volition whereas p-adic non-determinism is naturally the geometric correlate of imagination.

12.4.1 Could P-Adic Differential Equations Simulate Quantum Jump Sequence?

In practical applications one must idealize the biosystem with a system of differential or partial differential equations. Since cognition is basic aspect of living systems one might expect that the general properties of p-adic differential equations might be useful for modelling not only cognition but also the behavior of living matter.

1. The non-determinism associated with p-adic differential and partial differential equations is due to the presence of arbitrary functions depending on finite number of pinary digits of

p-adic coordinates, which are in the role of the integration constants. p-Adic integration constants are actual constants below some p-adic time scale. Solution of field equations typically consists of regions which are deterministic in the ordinary sense of the world glued to each other. Various conserved quantities are pseudo constants. This means that p-adic reality is somewhat like the reality of dreams consisting of fragments which could be realized also in everyday reality.

2. p-Adic space-time sheets could provide a simulation for the time development occurring via quantum jumps. p-Adic space-time surface would consist of fragments for which p-adic integration constants are ordinary constants. These pieces would represent the conscious information obtained about various real space-time surfaces in the sequence of quantum jumps (the space-time surfaces appearing in the quantum superpositions defined by the final states of quantum jumps are macroscopically equivalent). The lack of well-orderedness of the p-adic topology could reflect the fact that the arrow of time associated with t is only statistical.

3. p-Adic realization of the Slaving Hierarchy [B22] roughly means that there is a hierarchy $.. < p_1 < p_2 < ...$ of p-adic dynamics and that the integration constants at level p_1 (slave) obey some dynamic equations at some higher p-adic level $p_2 > p_1$ (master) and are actual constants below length scale $L_{p_2} > L_{p_1}$ for each pair in the sequence. This hierarchy of dynamics need not be completely deterministic. If Kähler action allows non-unique classical histories, the p-adic integration constants can be chosen to some degree freely at each level of the Slaving Hierarchy. The free choice of p-adic integration constants has interpretation as a plan of an intelligent system for its future behavior. At p- adic length and time scales (macroscopic!) it is possible to “break physical laws”: Universe learns engineering skills and begins to plan its own future!

4. The real counterparts for the solutions of p-adic differential equations have characteristic large jumps followed by small scale zig-zag type behavior. This zig-zag behavior is observed also for analytic solutions containing only ordinary integration constants, say for $x = At^2, y = Bt$ at values $t = 2^n$. Since p-adic integration constants are actual constants only for time scales smaller than $\Delta t = 2^{-n}$, the nondeterminism appears also as sudden jumps concentrated at multiples of Δt: Δt defines clearly a natural unit of time and therefore biological clock. In [B24] the generality of this zig-zag motion in all length scales was emphasized as one of the characteristics of biosystems and the sudden jumps were identified as jumps from strange attractor to another and small scale motion as motion along attractor. A good example of this kind of motion is the motion of eye [B24]. The fractal property of solutions of p-adic differential equations implies an infinite number of time scales corresponding to $\Delta_m = p^{-m}$, $m \leq n$. This in turn implies characteristic $1/f$ spectrum for the Fourier transform of orbit, which is quite general feature of biosystems [B24].

5. An important property of p-adic differential equations suggested by the iteration of simpls p-adic maps (say $Z \rightarrow Z^2$) in algebraic extensions of R_p is that critical orbits form a set ($|Z| = 1$), which possesses same dimension as the WCW so that critical metastable orbits are therefore not rare occurrences like in ordinary dynamics based on real topology. The small scale zig-zag motion between large jumps in the motion described by p-adic differential equations could correspond to motion near metastable orbit and be analogous to the motion along strange attractor in the strange attractor model of information processing proposed in [B24].

12.4.2 Information Filtering And P-Adics

Intelligent systems are extremely effective information filters. Only an extremely small amount of information is absorbed from the incoming information. As far as visual observations are considered it is the angles and boundaries, which receive most attention [B24]. An interesting possibility is that intelligent system concentrates its attention to p-adic super-conformal invariants such as angles. This would apply quite generally: any observation correspond to an orbit in some internal WCW simulating the observed system. The correspondence between the observation and simulation is determined only modulo p-adic super-conformal transformations of the configuration space.

One can even consider a simple model for the coupling between internal WCW and outer world using "Newton's equations" assuming that acceleration corresponds to the sensory experience:

$$\frac{d^2x^k}{dt^2} = F^k(t) - k\frac{dx^k}{dt} . \tag{12.4.1}$$

$F^k(t)$ describes observation as an external force acting on system. In the absence of $F^k(t)$ motion is linear (no angles!) and only when $F^k(t)$ is non-vanishing the direction of motion changes direction (angle). The friction term guarantees that constant stimulus leads to no sensory experience situation (adaptation). Idealized case corresponds to delta pulses causing zig-zag type motion. Note that p-adic indeterminacy brings in certain degree of "subjectivity" and could provide a phenomenological model for the quantum nondeterminacy.

This kind of model could serve as a model of language analogous to that considered in [B24]. Individual phonemes correspond to linear part on the orbit in some WCW and the duration of phoneme doesn't matter. The change of phoneme to another one corresponds to angle on the orbit (external force) and different angles correspond to different phoneme pairs. The hierarchy of structures (phonemes, hyphens, worlds, sentences, ..) might correspond to p-adic slaving hierarchy (say, $p = 2, 3, 7, 127..$) associated with the differential equations governing the orbit in internal WCW .

12.5 P-Adic Probabilities And Biosystems

p-Adic probabilities can be defined in a way analogous to that used to define ordinary probabilities [A5]. One can consider sufficiently large number of observations N chosen by some criterion since conditional probabilities are considered in practice and observe possible mutually exclusive outcomes N_i labeled by integer i. The relative frequencies N_i/N are estimates for p-adic probabilities. Probability conservation corresponds to the condition $\sum_i N_i = N$. The feature, which differentiates between ordinary and p-adic probabilities is related to the large N limit, which must exist in p-adic rather than ordinary sense. This means that the values of N, which differ by large powers of p are p-adically near to each other. For example, N and $N + 1$ are in general not near each other p-adically! For large values of p say $p = M_{127} \simeq 10^{38}$ the value of N rarely exceeds the critical value p and there is no practical difference between p-adic and ordinary probabilities. For small values of p the situation changes.

12.5.1 Does P-Adic Probability Apply Only To Cognition?

p-Adic probability concept is expected to apply in quantum statistical models of cognition. If p-adic space-time sheets indeed model sequences of quantum jumps by replacing consciously observed pieces of real space-time appearing in the sequence of quantum jumps by finite space-time regions glued to each other in p-adically continuous manner, then p-adic statistics might apply as a model of self-organization resulting from a dissipative time development by quantum jumps.

p-Adic probabilities might be natural in the statistical description of fractal structures resulting in the self-organization, and which by definition can contain same structural detail with all possible sizes.

1. Consider counting of conformally invariant structural details of a p-adic fractal. A simple biologically interesting example is the solution curve of p-adic differential equations in some configuration space associated with biosystem (say the space of average chemical concentrations). The angles associated with the kinks of the curve measured with some finite precision are the structural details in question.

2. One can count how many times i: th structural detail appears in a finite region of the fractal structure: although this number is infinite as real number it might possess (and probably does so!) finite norm as p-adic number and provides a useful p-adic invariant of the fractal. One can calculate also the total number of structural details defined as $N = \sum_i N_i$ and also define p-adic probability for the appearance of i: th structural detail as relative frequency

$p_i = N_i/N$. The real, "renormalized" counterparts of N_i and P_i obtained via the canonical correspondence define real valued invariants of the fractal structure.

3. The evaluation of the p-adic probabilities of occurrence can be done by evaluating the required numbers N_i and N in a given resolution. Better estimate is obtained by increasing resolution and counting the numbers of the hitherto unobserved structural details. The increase in the resolution greatly increases the number of observations in case of p-adic fractal and the fluctuations in the values of N_i and N increase with resolution so that N_i/N has no well defined limit as real number although one can define the probabilities of occurrence as resolution dependence concept. In p-adic sense the increase in the values of N_i and fluctuations is small and the procedure should converge rapidly so that reliable estimates should result with quite a reasonable resolution.

12.5.2 Is Small-P P-Adic Statistics Possible?

There is a distinct possibility that p-adic statistics with small p might be a unique testable signature of intelligent systems! The replication property of biosystems suggests that the lowest level in topological condensate of biosystem has $p = 2$. The quantization of the number of observations in biological experiment could be understood in the following manner. A natural choice for N in biosystem corresponds to all individuals that have existed or exist in the biosystem during some time interval. For an ideally replicating biosystem this number develops during time in the following manner. $N = 1$ for zeroth generation, $N = 1 + 2 = 3$ for the second generation, $N = 1 + 2 + ...2^k = 2^{k+1} - 1$ for $k + 1$: th generation. The expression for the relative frequency is

$$P = \frac{\sum_k N_k}{\sum_k 2^k} \ . \tag{12.5.1}$$

The dominating contribution to p-adic probability comes from the lowest generations. For p-adic probability to make sense the behavior of the system must be sufficiently deterministic during the earliest stages of the development. Non-determinism becomes possible for large of N. The development of the embryo during the first cell divisions is indeed highly deterministic process.

An interesting feature of the ideally replicating biosystem is that $N = 2^{k+1} - 1$ is Mersenne prime for certain values of the generation number $k + 1$. If the topological condensate associated with biosystem contains also higher levels p then these values of N might mean the emergence of something new since the value of N exceeds the critical value $p = M_{k+1}$, when the number generations becomes $k + 1$ and p-adic probability concept begins to apply at p: th level. This suggests that the values of the total cell number $N_{cell} = 2^{k-1}$ associated with the Mersenne primes M_k are critical cell numbers. Some of the lowest critical generation numbers are $k = 2$: $N_{cell} = 2$, $k = 3$: $N_{cell} = 4$, $k = 7$: $N_{cell} = 64$, ...

12.5.3 The Concept Of Monitoring

In p-adic quantum theory expected to provide a model for cognition one must somehow associate real probabilities to p-adic probabilities. This problem has been already discussed and leads to the conclusion that the transition probabilities of p-adic quantum system depend on how it is monitored. p-Adic sum of transition probabilities corresponds to the experimental situation, when one does not monitor individual transitions but using some common experimental signature only looks whether the transition leads to this set of finals states or not. When one looks each transition separately or effectively performs different experiment by considering only one transition channel in each experiment one must use the sum of real probabilities. More precisely, the choice of experimental signatures divides the set U of the final states to disjoint union $U = \cup_i U_i$ and one must define the real counterparts for transition probabilities P_{iU_k} as

$$\begin{aligned} P_{iU_k} &= \sum_{j\in U_k} P_{ij} \ , \\ P_{iU_k} &\rightarrow (P_{iU_k})_R \ , \\ (P_{iU_k})_R &\rightarrow \frac{(P_{iU_k})_R}{\sum_l (P_{iU_l})_R} \equiv P^R_{iU_k} \ . \end{aligned} \tag{12.5.2}$$

Similar resolution can be defined also for initial states by decomposing them into a union disjoint subsets. The assumption means deep difference with respect to the ordinary probability theory.

p-Adic probability conservation implies that the lowest order terms for p-adic probabilities satisfy the condition $\sum_j P^0_{ij} = 1 + O(p)$. The general solution to the condition is $P^0_{ij} = n_{ij}$. If the number of the final states is much smaller than p this alternative implies that real transition rates are enormous: typically of order p! Therefore it seems that one must assume

$$P^0_{ij} = \delta(i,j) \ . \tag{12.5.3}$$

As a consequence the probability for anything to happen (no monitoring of different events) is given by

$$\sum_j (P_{ij} - \delta(i,j)) = 0 \ , \tag{12.5.4}$$

and vanishes identically! This is not so peculiar as it looks first since there must be some signature for anything to happen in order that it can be measured and signature always distinguishes between two different events at least: it is difficult to imagine what the statement "anything did not happen" might mean! Of course, in real context this philosophy would imply the triviality of S-matrix.

If biosystems are indeed quantum systems and p-adic probabilities apply to their description then the unavoidable prediction is that the behavior of biosystems depends on how it is monitored (remembering all anecdotes about experimentation with living matter, one might somewhat light-heartedly argue that this is just the case!). For small values of p, in particular for $p = 2$, the deviations from the standard probability theory are especially large. In particular, the resolution of the monitoring is essential factor. It must be stressed that this peculiar behavior seems not to be related with the predictions of standard quantum measurement theory and this supports the view that p-adic probabilities apply only to the statistical modelling of cognition.

An alternative interpretation for the degenerate eigenvalues appearing in the definition of monotoring has emerged years after writing this. The sub-spaces corresponding to given eigenvalue of density matrix represent entangled states resulting in state function reduction interpreted as measurement of density matrix. This entanglement would be negentropic and represent a rule/concept, whose instances the superposed state pairs are. The information measure would Shannon entropy based on the replacement of the probability appearing as argument of logarithm with its p-adic norm. This entropy would be negative and therefore measure the information associated with the entanglement. This number theoretic entropy characterizes two particle state rather than single particle state and has nothing to do with the ordinary Shannon entropy.

Maybe one could say that finite measurement resolution implies automatically conceptualization and rule building. Abstractions are indeed obtained by dropping out the details.

12.6 Is Small-P P-Adicity Possible?

A longstanding problem of TGD inspired theory of consciousness and p-adic TGD in general has been whether small-p p-adicity is present in macroscopic length scales. The basic form of p-adic length scale hypothesis suggests that small-p p-adicity should be present only in length scales near CP_2 size about 10^4 Planck lengths, which defines the fundamental p-adic length scale. On the other hand, p-adic fractality suggests that also the scaled up versions of entire p-adic length scale hierarchy might be possible in the sense that CP_2 size is effectively replaced with p-adic length scale L_p for any prime p and most probably for primes $p \simeq 2^k$, k power of prime. In particular, the realization of genetic code, which corresponds to p-adic prime $p = 127$, at the level of DNA molecules suggests, that small-p p-adicity is realized in Nature and involves transmutation of the fundamental p-adic length scale to atomic length scale. This expectation conforms also with the idea that Universe is infinite-sized self-organizing quantum computer emulating itself in all possible scales and building scaled up simulations of the lower levels. Even science could be regarded as one such emulation.

There are two ways to achieve this transmutation. Either there is some mechanism making this transmutation possible dynamically or the scaled up variants of the p-adic length scales are present from the beginning. I constructed long ago an argument suggesting that the first option might be possible. If one accepts the hierarchy of Planck constants, this hierarchy is present from the beginning at the level of dark matter but manifesting itself also in the behavior of the visible matter since dark matter and visible matter interact in TGD framework via the standard interactions such as classical em fields and photon exchange. What darkness means that particles at different pages of the Big Book realizing dark matter hierarchy cannot appear in the same local interaction vertex of Feynman diagram so that in particle physics laboratory these interactions cannot be observed.

12.6.1 Hierarchy Of Planck Constants And Small-P P-Adicity

The hierarchy of Planck constants [K92, K92, K71, K40] realizes small-p p-adicity in a very natural manner.

1. p-Adic length scale hypothesis states that the hierarchy of primary p-adic length scales $L_p = \sqrt{p}R$, where R is CP_2 size is fundamental. The primes near power of 2 are favored so that the primary p-adic length and time scales would come as half octaves. The justification for the hypothesis came originally from p-adic mass calculations and Uncertainty Principle.

2. The secondary p-adic time (and length) scales $T_{p,2}$ associated with primes $p \simeq 2^k$ coming as octaves of CP_2 scale define the proper time temporal distances between the tips of CDs (and their spatial sizes). The secondary p-adic length scales are analogous to the horizon sizes in cosmology. p-Adic length scale hypothesis follows from a simple argument using the light-like randomness of 3-surfaces implying that primary p-adic length scale is proportional to a square root of the temporal distance between the tips of CD.

3. The basic prediction of the generalization of quantum theory by allowing a hierarchy of Planck constants is that for $r = \hbar/\hbar_0$ the primary p-adic length scale L_p is scaled to $\sqrt{r}L_p$ and secondary p-adic time scale to $rL_{p,2}$. In principle all rational values of r are possible but certain rationals such as ratios and products and inverses of products of ruler-and-compass integers are favored. These integers are expressible as products of a power of two and product of different Fermat primes $F_k = 2^{2^k} + 1$. Only $k = 1, 2, 3, 4$ are known to give rise to prime.

4. Second interesting hierarchy of values of r are ratios, products and inverses of products of primes. The reason is that the quantum phases $exp(i2pi/p)$ behave as primes under multiplication in the sense that more general phases can be expressed as products of powers of these prime phases. This would give as a special case small prime multiples of the secondary p-adic length scales.

12.6.2 Hierarchy Of Planck Constants And Small-P P-Adicity In Gravitational Sector

The hierarchy of Planck constants [K92, K92, K71, K40] realizes small-p p-adicity in a very natural manner. The basic prediction is that for $r = \hbar/\hbar_0$ p-adic length scale L_p is scaled to $\sqrt{r}L_p$. In principle all rational values of r are possible but certain rationals such as ratios and products and inverses of products of ruler-and-compass integers are favored. These integers are expressible as products of a power of two and product of different Fermat primes $F_k = 2^{2^k} + 1$. Only $k = 1, 2, 3, 4$ are known to give rise to prime.

Gravitational Planck constant expressible as $\hbar_{gr} = GM_1M_2/v_0$, wehere $v_0/c < 1$ is not too far from unity, is extremely large. Using $L_p = \sqrt{p}R$, and $R = k10^4\sqrt{G/\hbar}$ one obtains that for the scaled up p-adic length scale the expression

$$L_p \rightarrow \sqrt{\frac{GM_1M_2}{v_0}}L_p = \sqrt{\frac{p}{v_0}}G\sqrt{M_1M_2} \ .$$

For $M_1 = M_2 = M$ which makes sense if one consider self-gravitation one has

$$L_p \rightarrow \sqrt{\frac{GM^2}{v_0}}L_p = \frac{1}{2}\sqrt{\frac{p}{v_0(S)}}r_S \ .$$

where $r_S = 2GM$ is Schwartschild radius. One can ask whether the well-known Titius-Bode law [E5] stating an approximate quantization of orbital radii via formula $r = r_0 + r_1 2^k$ might relate to the p-adic length scale hypothesis for small primes. The powers 2^k, $k = 1, 2, ..., 8$ correspond to primes $p = 2^k + \epsilon$ for either sign of k. The radii of Bohr orbits come as $n^2 r_S/v_0$ and produce for $v_0 \simeq 2^{-11}$ reasonable fit for the orbital radii of the 4 inner planets for $n = 3, 4, 5, 6$. For outer planets the scaling $v_0 \rightarrow v_0/5$ is required. This would give the approximate formula

$$p(n) \simeq log(\frac{4n^4 v_0(S))}{v_0^2})$$

for the inner planets and

$$p(n) \simeq log(\frac{100n^4 v_0(S))}{v_0^2})$$

for the outer planets. The corresponding time scales would come as approximate octaves of the same basic time scale and would be of order few minutes.

Since electron corresponds to a huge prime $p = 2^{127} - 1$, one can consider the possibility that relatively small p-adic primes in this scale give rise to biological time scales and that the periodicities which appear in living matter as prime multiples of year might be understood in terms of dark matter at space-time sheets mediating gravitational interaction.

For Earth the Schwartschild radius is $r_S \simeq .9$ cm so that for $v_0(E) = 2^{-11}$ one would have the basic scale of.4 m and p-adic length scale hypothesis for small values of p would give half octaves of this scale. These scales need not have anything to do with biology.

12.6.3 Small-P P-Adicity And Hydrodynamics

Hydrodynamic turbulence in the atmosphere involves generation of coherent macroscopic structures which are typically structures appearing in excitable media. One example are spiral waves which represent spiral like convective roll pattern such that the radius of the rolling vortex increases exponentially when one moves away from the apex of the spiral wave. Tornadoes and hurricanes are also well known self-sustaining structures. The generation of these structures is difficult to understand in ordinary hydrodynamics and Indian meteorologists Mary Selvam [H6] takes as her challenge to understand the microscopic mechanism leading to the generation of these structures. TGD suggests quite generally the reduction of the hydrodynamical turbulence and chaos in excitable media to magnetic or Z^0 magnetic turbulence. The work of Selvam related to the turbulent atmospheric flows inspires also additional very interesting insight to p-adic length scale hypothesis and suggests that n-ary p-adic length scales $L_e(n,k)$ corresponding to very large values of n are realized in hydrodynamical turbulence, and that hydrodynamical vortices could be regarded as elementary particle like objects on the space-time sheets at which they are condensed topologically.

Spiral waves and magnetic turbulence

Self-sustaining spiral waves are known to be characteristic for all excitable media [A1] and typical results of self-organization. The growth of plants leads quite generally to the generation of logarithmic spirals; spiral Ca_{++} waves are known to be crucial for intracellular communications [A29] ; spiral waves appear also in heart [A4] [A4, A17].

1. Logarithmic spiral and Penrose tilings

Spiral waves (say roll-vortices with vortex core along spiral) are waves for which the center of the wave defined by logarithmic spiral

$$\frac{R}{r} = exp(b\theta) \ .$$

The values of R/r are Fibonacci numbers $F(n+1) = F(n) + F(n-1)$ for certain values of the angular variable θ. At the limit of large Fibonacci numbers one has $F_n \simeq \tau^n$ and substituting to the equation one obtains $\theta \simeq n\theta_0$, $\theta_0 = log(\tau)/b$, $\tau = \frac{1+\sqrt{5}}{2}$.

Logarithmic spirals form a one-parameter family and especially interesting is the logarithmic spiral for which the line connecting the points $r = F_n$ and $r = F(n+1)$ has length F_n. In this case

$$\theta_0 = \frac{2\pi}{10} = 36 \ \text{degrees} \ .$$

This particular logarithmic spiral leads to a generation of Penrose tiling [A31]: this occurs in both 2- and 3-dimensional case. This particular logarithmic spiral is very general in botany. Rather interestingly, the angle of 36 degrees happens to be the angle between two subsequent DNA nucleotides in DNA helix, which encourages to consider the possibility that the helical structure of DNA rather concretely codes is in some sense fractal growth defined by the logarithmic spiral with this value of b. Note that this kind of growth preserves shape and this is probably one reason for why logarithmic spirals appear so often in botany. In fact, the notion of many-sheeted DNA [K55] suggests that genes in DNA helix in some sense represent contracted versions of the organism preserving 1-dimensional homology: perhaps the contraction preserves also spiral structure. A further interesting point to notice is that the shortest sequence of DNA: s for which the net winding angle along helix is multiple of 2π and which codes for an entire protein consisting of 30 DNA nucleotides, has thickness of cell membrane as already found.

2. Reduction of chaos to magnetic turbulence?

TGD suggests that quite generally spiral waves are accompanied by the underlying magnetic and Z^0 magnetic flux tube structures. Spiral wave would correspond to Z^0 flux tube around which ordinary matter rotates so that rolling vortex results. At the apex magnetic flux tube apparently ends. The conservation of (Z^0) magnetic flux requires that flux tube leaves the space-time sheet at the apex and continues at the second space-time sheet. This suggests the fascinating possibility that macroscopic structures in hydrodynamic wormhole magnetic fields [K121] associated with pairs of space-time sheets and be generated by rotating wormholes at the boundaries of the structure. If time orientation is negative at second space-time sheet, this space-time sheet carries negative energy density which can be very small if only the energy of Z^0 magnetic field is in question. If wormhole magnetic fields (besides MEs) represent mind-like space-time sheets of finite time duration, one could perhaps (rather loosely) speak about interaction of matter and mind. The same mechanism might be at work also at cell level.

3. Magnetic turbulence and loss of macroscopic quantum coherence

For superconductors quantization conditions imply that the increment of the phase of the complex order parameter of the supra phase around the circuit along boundary of the flux tube equals to the magnetic flux through the tube. Thus magnetic turbulence implies turbulence of superconductor and probably destruction of the supraphase. If ionic superconductors are responsible for biocontrol, then magnetic turbulence would be reflected as chaotic functioning of organ. This loss of quantum coherence would be caused by the leakage oft he supra currents from flux tubes via flux tubes. This in turn would imply dissipation at the non-superconducting space-time sheets by particle collisions. This leakage would be forced by the inertia when the local curvature of the flux tube becomes too large: this is indeed expected to occur in a chaotic situation when flux tubes have very Brownian shapes.

Heart failure, known to involve the generation of decaying spiral waves modellable using Hodkin-Huxley equations or their variants [A4, A17], might be one example of this mechanism. The reduction of this model to quantum level is required by internal consistency if one takes seriously TGD based model of nerve pulse activity in terms of ionic and electronic superconductors relying crucially on Josephson junctions associated with axons [K82]. In case of heart, normal situation would in ideal case correspond to spatially constant phase wave of Josephson current oscillating in time with basic frequency (there is precise analogy with a rotating mathematical pendulum) so that the Josephson currents associated with all heart cells oscillate in unisono, perhaps at the rhythm of heart beat. During heart failure magnetic turbulence destroys this coherence. Interestingly, the time period of fibrillation is .1 seconds, the time scale of the memetic code [A4].

4. Atmosphere as cortex of Mother Gaia?

In TGD framework self-organization means the presence of conscious selves and suggests that even atmosphere is in some sense part of Mother Gaia. Perhaps it is of some significance that the ratio of the thickness of atmosphere (10 km) to the radius of Earth radius is of order 1/100 and is same as the ratio of cell membrane thickness to cell size. Fractality indeed suggests this ratio if atmosphere is regarded as scaled-up version of the cell membrane. Note however that the thickness of flora is about 10 m: in case of cell membrane this would suggest a layer of thickness of order 10^{-11} meters, which happens to correspond to the p-adic length scale $L_{M_{127}}$ associated with electron. The p-adic prime associated with the memetic code pops up again and one could wonder whether the MEs with length of $L_2(127)$ could have thickness equal to $L_e(127)$ and form structure analogous to biosphere at surface of Earth. The fact, that the frequency distribution of so called sferics, em perturbations induced by lightnings resemles at low frequencies delta band in sfericsbrain, suggests that these exotic levels of life might be there and interact with animal brains.

Selvam's model and claims

Selvam studies a model for hydrodynamical spiral waves by assuming that these waves are vortices with core at logarithmic spiral

$$z \equiv \frac{R}{r} = b \times exp(b\theta) \ .$$

Selvam assumes also that the radius ρ of rolling convective vortex grows with z and that also this growth obeys similar law: that is $\rho = exp(b\theta)$. Selvam assumes that the parameter θ_0 corresponds to the angle of 36 degree associated with equilateral Fibonacci triangle having short sides F_n and long side $F(n+1)$ at the limit $n \rightarrow \infty$. As noticed, this logarithmic spiral gives rise to Penrose tiling.

Selvam does not specify precisely this growth law: for instance, whether there is phase lag between R characterizing position of growing vortex and r characterizing its size. Selvam does not either clearly specify how R develops with time: for instance, whether growth occurs linearly in which case θ would grow logarithmically. One possible manner to obtain the proposed growth is to assume that the growth is analogous to biological growth such that turbulent eddies are in the role of cells and replicate. If the growing vortex decomposes of radius $\rho(n)$ to an inner cylinder of thickness $\rho(n-2)$ and outer annulus of thickness $r(n-1)$ such that outer annulus replicates to annulus of same thickness at $n+1$:th step of growth process one indeed obtains $\rho(n+1) = \rho(n) + \rho(n-1)$ giving rise to Fibonacci sequence asymptotically.

Selvam claims that the dominating temporal periodicities T_n of flow are Fibonacci numbers in suitable units:

$$T_n = F(n) \simeq \tau^n \ , \quad \tau = \tfrac{1+\sqrt{5}}{2} \ .$$

This claim can be understood if vortex structures with radius F_n form special structures and if there are standing waves moving with constant velocity v along these structures: this gives

$$T_n = \frac{F_n r}{v}$$

for the periodicities of these waves. Selvam argues that Fibonacci numbers reflect also the periodicities of prime number distribution but I find it difficult to understand the motivations for this claim.

Selvam also studies the distribution for the ratio $z = R/r$ of large vortex radius R to smallest vortex radius r, and, as far as I have understood correctly, claims that this distribution is the same as the distribution of primes in region of rather small primes. This could be understood if vortex radii are prime multiples of r

$$R = kr \ , \ k \text{ prime} \ ,$$

and if each prime appears with the same probability. This assumption can be actually loosened: one can also interpret r as the p-adic length scale associated with minimum size vortex interpreted as space-time sheet. Even the assumption that vortices sizes are given by primes might be too strong: only one-one correspondence with the distribution of primes is needed. Selvam also argues that vortex dynamics has quantal features and that vortices could in some aspects be regarded as quantum objects: this is certainly what TGD approach strongly suggests.

It must be emphasized that the arguments of Selvam do not satisfy the requirement of mathematical rigour and it is only my personal feeling that something deep is involved and I just take Selvam's claims as inspiration for studying whether small-p p-adicity suggested strongly by fractality might be realized in hydrodynamical flows. Certainly, TGD predicts p-adic evolution and this evolution should reflect itself directly in biological growth and perhaps even in hydrodynamical self-organization. Also Matthew Watkins has proposed a connection between evolution and prime numbers [A28].

p-Adic evolution and quantum classical correspondence (classical dynamics should provide a Bohr orbit type representation for quantum dynamics) suggests that growth processes quite generally corresponds to p-adic evolution. First pop-up structures with $p = 2$, then structures with $p = 3$, and so on. In hydrodynamics case these structures correspond to stable vortices with prime-valued radius $R/r = p$. If the growth of spiral wave is linear in time then vortices with prime valued radio pop-up for the first time at time values which are prime multiples of basic time unit. If the emergence of these vortices reflects itself as some kind of distinguishable feature in the temporal behavior of dynamical quantities, as one might expect, the Fourier spectrum should reflect the properties of the spectrum of prime numbers. This is clearly a strong and testable prediction.

Why vortices with prime radii are stable?

The first question to be answered is why vortices with radii which are prime valued are stable. Suppose that there is fundamental length scale r identifiable as the radius of turbulent eddy. This radius would result from the quantization of Z^0 magnetic flux if one assumes that there is a preferred value for the strength of the Z^0 magnetic field. Flux quantization would imply that the radii of the vortices are quantized as $r \propto \sqrt{n}$, n integer. The problem is to understand why n is square of prime rather than arbitrary integer.

One could however correspond the possibility that prime valued radii correspond to secondary p-adic lengths scales with a scaled-up fundamental p-adic length scale defined by the Z^0 magnetic flux quantization (a possible mechanism leading to transmutation of the fundamental p-adic length scale will be discussed later). This implies that all vortices (cylindrical and annular) have radius which is integer multiple of this length scale: $z = n$. Vortices consists of turbulent eddies or tend to decay to vortices $z = 1 < m < n$. The wavelengths of the radial perturbations tending to induce the decay of the vortices to smaller ones, are integer multiples of r. One has effectively aperiodic lattice, Penrose tiling known to be associated with logarithmic spirals [A31]. Also in the periodic lattice only integer multiples of the basic wave vector propagate. Turbulent eddy defines the equivalent of fundamental lattice cell.

As a consequence, only vortices with prime-valued radii are stable. For instance, $n = p_1 \times p_2$, p_1 and p_2 primes, the vortex can decompose to p_1 cylindrical or annular vortices with radius p_2 or vice versa by a perturbation with wavelength $\lambda = p_1 r$ $(p_2 r)$. The impossibility to generate radial periodic perturbations with wavelength which is nontrivial multiple of the fundamental length, explains why prime vortices are stable against decay. Note that in [K89] precisely the same argument was used to explain why some retarded persons are able to "see" factorization of 8-digit numbers into prime factors (see the book "The man who mistook his wife for hat" of Oliver Sacks [J62]). Mental images representing number n, is represented by some structure, perhaps vortex(!), and if n is not prime it has tendency to decay to some number of identical smaller structures! Thus non-primeness is directly visible property: perhaps higher levels selves spend their time by monitoring the factorization of very large integers.

How the transmutation of a fundamental p-adic length scale to macroscopic length scale could occur?

What might be the mechanism effectively leading to the transmutation of the fundamental p-adic length scale $l \simeq 10^4$ Planck lengths to a macroscopic length scale? Hierarchy of Planck constants represents one solution to the problem. A possible p-adic explanation for these length scales would be as secondary p-adic length scales for Planck constants, which correspond to a prime multiples of the ordinary Planck constant: $r = \hbar/\hbar_0 = p$. Since electron corresponds to a secondary p-adic length scale of order Earth's radius the primes in question must be smaller than M_{127}. Some examples are in order.

1. $k = 113$, which corresponds to nuclear p-adic length scale and Gaussian Mersenne, would correspond to a secondary p-adic length scale 1.831 km. Prime multiples of this scale identified in terms of hierarchy of Planck constants might have something do with the radii of vortices reported by Selvam.

2. The p-adic length scale defined by M_{107} assignable to the hadronic space-time sheets would correspond to a secondary p-adic length scale of 28.6 meters. The secondary p-adic length scale assignable to M_{89} characterizing intermediate gauge bosons would be.1 millimeters defining the size scale of a large neuron and also the size of water blob having Planck mass. The mapping of elementary particle p-adic length scales to secondary p-adic length scales defining size scales of CDs would mean a correlation between elementary particle physics and macroscopic physics in human length and time scales, which has remained hidden.

3. The primary p-adic length scale $k = 137$ assignable to atom corresponds to the secondary p-adic time scale of 102.4 seconds. The corresponding length scale, which is 2^{10} times the circumference of Earth, is $r = 61$ Gm. The distance of Earth from Sun is $AU = 149$ Gm and about 5/2 times this distance.

12.6.4 2-Adic Psychophysics?

Music metaphor has turned out to be of crucial importance for the theory of qualia. The most natural explanation for this is that music metaphor reflects underlying 2-adicity of our sensory experience. Perhaps at least some aspects of our experience result from a mimickry of the lowest level of the p-adic self-hierarchy. Taking 2-adicity seriously, one is forced to ask for the possible consequences of 2-adicity. For instance, could it be that at the level of primary qualia the intensity of sensation as function of stimulus depends on the 2-adic norm of the 2-adic counterpart of the stimulus and is thus a piecewise constant function if sensory input?

An observation supporting this speculation is following. When over-learning occurs in tasks involving temporal discrimination, the intensity of sensation as a function of stimulus deviates from smooth logarithmic form in small scales by becoming piecewise continuous function [J43] such that the plateaus where response remains constant are octaves of each other. This observation suggests a generalization inspired by 2-adic version of music metaphor. Primary quale has multiple of cyclotron frequency as its correlate and, being integer valued, is essentially 2-based logarithm of the 2-adic norm for the 2-adic counterpart of the intensity of the sensory input. Hence the increase of intensity of the sensory input by octave correspond to a jump-wise replacement of the n: th harmonic by n+1: th one and should be seen in EEG. Our experience usually corresponds to the average over a large number of this kind of primary experiences so that underlying 2-adicity is smoothed out. In case of over-learning or neurons involved act unisono and the underlying 2-adicity is not masked anymore. At the level of ELF selves this would mean generation of higher harmonic when the number of nerve pulses per unit of time achieves threshold value allowing the amplification of corresponding frequency by the mechanism discussed already earlier.

12.6.5 Small-P P-Adicity In Biosystems And Psychophysics

There are several hints for small-p p-adicity in macroscopic length and time scales from biology and psychophysics besides this decisive result of Selvam.

1. 2-Adicity of music experience suggests that 2-adicity present in macro-temporal scales [K89]. Also the general form of the p-adic length scale hypothesis and the concrete appearance of 2-adic fractals [K65] suggests that 2-adicity is realized also in macroscopic length scales. The topological model for thoughts as association sequences suggests strongly small-p p-adicity and this idea was in fact one of the first ones relating p-adic numbers with consciousness. The 2-adicity of music experience is relatively easy to understand if any p-adic time scale can serve as effective fundamental time scale for 2-adicity of music experience. Note however that by p-adic length scale hypothesis the fundamental time scales come as powers of 2. The apparently complete freedom to choose the fundamental time scale can be understood if practically any p-adic time scale L_p replacing l can serve as effective fundamental time scale.

2. Genetic code corresponds to $p = 127 = 2^7 - 1$ in TGD inspired model of abstraction process predicting infinite hierarchy of "genetic codes" [K43]. It should be however realized in macrotemporal scales rather than near CP_2 time scale and if the proposed mechanism scales l to p-adic length scale of order atomic length scale this is indeed realized.

3. Memetic code corresponds to $p = 2^{127}-1$ and to a unique p-adic time scale of .1 seconds [K43]. Codeword has 126 bits and single bit corresponds to the time scale of nerve pulse. What is disturbing that this would make time scale of human brain unique. Situation changes if any p-adic time scale can take the role of fundamental p-adic time scale so that .1 seconds would become lower limit for time duration of memetic code word. Hence brain would represents the first step in the evolution creating memetic codes in longer time scales. In light of p-adic fractality the idea that the time scale associated with M_{127} is the only possible duration of memetic codon, does not sound plausible. One can indeed imagine a hierarchy of scaled-up versions of M_{127} code. This would suggest that M_{127} could be also realized at time scales $k \times T_2(127)$, k prime, $T_2(127) = .1$ s. $T_2(127)$ would be the smallest p-adic time scale, where memetic code is possible and the distribution of longer time scales would obey distribution of primes. This distribution should reflect itself in the EEG spectrum at very low frequencies.

12.6.6 Is Evolution 3-Adic?

I received an interesting email from Jose Diez Faixat giving a link to his blog (`http://tinyurl.com/ycesc5mq`). The title of the article in the blog is "Bye-bye Darwin" and tells something about his proposal. The sub-title "The Hidden rhythm of evolution" tells more. Darwinian view is that evolution is random and evolutionary pressures select the randomly produced mutations. Rhythm does not fit with this picture. Faixat published 1993 the first article about his observations in the journal World Futures Vol. 36, pp. 31-56, edited by Ervin Lazlo with the title "A hypothesis on the rhythm of becoming" [I70, I71].

The observation challenging Darwinian dogma is that the moments for evolutionary breakthroughs - according to Faixat's observation - seems to come in powers of 3 for some fundamental time scale. There would be precise 3-fractality and accompanying cyclicity - something totally different from Darwinian expectations.

By looking at the diagrams demonstrating the appearance of powers of 3 as time scales of evolution, it became clear that the interpretation in terms of underlying 3-adicity could make sense. I have speculated with the possibility of small-p p-adicity. In particular, p-adic length scale hypothesis stating that primes near powers of 2 are especially important physically could reflect underlying 2-adicity. One can indeed have for each p entire hierarchy of p-adic length scales coming as powers of $p^{1/2}$. $p = 2$ would give p-adic length scale hypothesis. The observations of Faixat suggest that also powers p=3 are important - at least in evolutionary time scales.

Note: The p-adic primes characterizing elementary particles are gigantic. For instance, Mersenne prime $M_{127} = 2^{127} - 1$ characterizes electron. This scale could relate to the 2-adic scale $L_2(127) = 2^{127/2} \times L_2(1)$. The hierarchy of Planck constants coming as $h_{eff} = n \times h$ also predicts that the p-adic length scale hierarchy has scaled up versions obtained by scaling it by n.

The interpretation would be in terms of p-adic topology as an effective topology in some discretization defined by the scale of resolution. In short scales there would be chaos in the sense of real topology: this would correspond to Darwinian randomness. In long scales p-adic continuity would imply fractal periodicities in powers of p and possibly its square root. The reason is that in p-adic topology system's states at t and $t + kp^n$, $k = 0, 1, ...p - 1$, would not differ much for large values of n.

A possible interpretation relies on p-adic fractality [K65] (http://tgdtheory.fi/figu.html). p-Adic fractals are obtained by assigning to real function its p-adic counterpart by mapping real point by canonical identification

$$\sum_n x_n p^n \to \sum_n x_n p^{-n}$$

to a p-adic number, assigning to it the value of p-adic variant of real function with a similar analytic form and mapping the value of this function to a real number by the inverse of the canonical identification, the powers of p correspond to a fractal hierarchy of discontinuities.

A possible concrete interpretation is that the moments of evolutionary breakthroughs correspond to criticality and the critical state is universal and very similar for moments which are p-adically near each other.

The amusing co-incidence was that I have been working with a model for 12-note scale [L16], [K81, K115] (http://tinyurl.com/y7csuxaw), which to my opinion is highly interesting from the point of view of consciousness theory. Already the mathematicians of ancient Greece speculated with a connection with the geometry of Platonic solid and music scale [J68].

The basic observation is that icosahedron is a Platonic solid containing 12 vertices. The scale is represented as a closed non-self-intersecting curve - Hamiltonian cycle - connecting all 12 vertices: octave equivalence is the motivation for closedness. The cycle consists of edges connecting two neighboring vertices identified as quints - scalings of fundamental by factor 3/2 in Platonic scale. What is amusing that scale is obtained essentially powers of 3 are in question scaled down (octave equivalence) to the basic octave by a suitable power of 2. There is of course slight discrepancy due to the fact that $(3/2)^{12} = 2^7$ is not quite true. This motivated the transition to the well temperated scale with half note corresponding to the scaling by $2^{1/12}$.

The faces of icosahedron are triangles and define naturally basic 3-chords. Triangle can contain either 0, 1, 2 edges of the cycle meaning that the 3-chords defined by faces and defining the notion of harmony contain 0, 1, or 2 quints. One obtains large number of different harmonies partially characterized by the numbers of 0-, 1-, and 2-quint icosahedral triangles since the total number of Hamiltonian cycles at icosahedron is 2^{10}. One must howe$h_{eff} = n \times h$ver notice that those related by an isometry of icosahedron are equivalent.

The connection with 3-adicity comes from the fact that Pythagorean quint cycle is nothing but scaling by powers of 3 followed by suitable downwards scaling by 2 bringing the frequency to the basic octave so that 3-adicity might be realized also at the level of music!

There is also another strange co-incidence. Icosahedron has 20 faces, which is the number of amino-acids. This suggests a connection between fundamental biology and 12-note scale. This leads to a concrete geometric model for amino-acids as 3-chords and for proteins as music consisting of sequences of 3-chords. Amino-acids can be classified into 3 classes using polarity and basic - acid/neutrality character of side chain as basic criteria. DNA codons would would define the notes of this music with 3-letter codons coding for 3-chords. One ends up also to a model of genetic code relying on symmetries of icosahedron from some intriguing observations about the symmetries of the code table.

At the level of details the icosahedral model is able to predict genetic code correctly for 60 codons only, and one must extend it by a fusion it with a tetrahedral code. The fusion of the two codes corresponds geometrically to the fusion of icosahedron with tetrahedron along common face identified as punct (punct) and coded by 2 stopping codons in icosahedral code and 1 stopping codon in tetrahedral code. Tetrahedral code brings in 2 additional amino-acids identified as so called 21st and 22nd amino-acid discovered for few years ago and coded by stopping codons. These stopping codons certainly differ somehow from the ordinary ones - it is thought that context defines somehow the difference. In TGD framework magnetic body of DNA could define the context.

The addition of tetrahedron brings one additional vertex, which correlates with the fact that rational scale does not quite closed. 12 quints gives a little bit more than 7 octaves and this forces to introduce 13 note for instance, A_b and $G_\#$ could differ slightly. Also micro-tubular geometry involves number 13 in an essential manner.

12.7 L_0 Mod $P^M = 0$ Excitations Of Super Virasoro Algebra As Higher Forms Of Life?

Topological field quanta can have all possible sizes. Uncertainty Principle suggests that the size of the topological field quantum corresponds to the p-adic length scale of the corresponding 3-surface. This would mean that the vibrational excitations of even macroscopic 3-surfaces could correspond to Super Virasoro representations. Indeed, the states of real super-symplectic representations associated with the light-like boundaries of MEs have gigantic almost-degeneracies and provide excellent candidates for representing biological information [K70]. These representations realize the idea of quantum hologram in the sense of quantum gravity and quantum information theory concretely and emerge naturally also in the TGD based theory of qualia [K41] .

Besides this there are also what might be called exotic p-adic representations of super-conformal Super Virasoro algebra for which the real counterparts of the p-adic masses are extremely small although the masses of the corresponding real states are super-astronomical. These states have enormous quaternion-conformal (rather than only super-symplectic degeneracies) degeneracies and this raises the question about the possible biological relevance of these states. Thus it seems (at least now when I am writing this!) that the exotic states are not relevant for the understanding of biosystems. Despite this, and also because I ended up with super-symplectic representations via exotic p-adic representations, I do not have heart to throw away the discussion of the properties and possible biological significance of these representations. The reader can however safely skip this section if she wishes.

12.7.1 Exotic P-Adic Super-Conformal Representations

The eigenvalues of Super Virasoro generator L_0 are non-negative integers n. In p-adic context one can naturally decompose these eigenvalues into classes such that in class m eigen-values are of form $n = kp^m$, $k = 1, 2, ...,$ $k \ mod \ p \neq 0$. In class m the real counterpart of the mass squared is of order $1/p^m$ and hence extremely small for large values of m. Does this predict the existence of light excitations for all particles, even fermions?

1. The answer "No" is suggested by the fact that p-adic representations of super-conformal algebras should describe the physics of cognition rather than real physics so that these exotic states need not correspond to real physics states.

2. One might of course argue that every every p-adic state (imaginable state!) must have a real counterpart with essentially the same real physics properties. In recent case the real counterparts of the p-adic masses obtained by canonical identification are extremely small whereas the masses of the corresponding real states are super-astronomical if the value of the string tension is formally the same and of order $O(p^0)$. String tension is however a dynamical quantity and one can consider the possibility that the real counterpart of the p-adic string tension for the super-conformal representations is such that the real and p-adic mass scales are mutually consistent. Admittedly, this argument does not satisfy the requirement of mathematical elegance.

12.7.2 Elementary Particles Cannot Correspond To Exotic Super-Conformal States

If the real counterparts of the exotic states are created in pairs with vanishing total quantum numbers and having super-astronomical real masses, they certainly cannot have any relevance for elementary particle physics. If one assumes that string tension for real states is such that real masses of exotic states are of same order as p-adic mass situation can change. For instance, intermediate gauge bosons would have also excitations with mass $1/\sqrt{p}$ and one can wonder whether these excitations could correspond to the observed intermediate gauge bosons. One could even consider the possibility of understanding the entire elementary particle mass spectrum in terms of these $n = 0$ and $n = p$ excitations assuming that the vacuum weight of the Super Virasoro representations is vanishing. There are quite a number of consistency conditions, which definitely exclude this possibility.

1. Photon, graviton and gluon correspond to a ground state created by vanishing conformal weight. This happens to be the case. By a suitable choice for the coefficient of modular contribution and with a suitable choice of mass scale one might be able to reproduce charged lepton mass ratios correctly.

2. All states with non-vanishing ground state vacuum weight should correspond to $n = p$ states and would have same non-vanishing mass equal to $1/\sqrt{p}$ in natural units for given p. For quarks no mass splitting would result in first order approximation and the experience with CKM matrix suggests very strongly that it is not possible to achieve correct CKM matrix for mass degenerate u and d quarks.

3. A strong counter argument against the scenario is the huge ground state degeneracy of the states expected. As well known the degeneracy of states with eigenvalue n of L_0 increases exponentially as a function of n. For instance, huge number of color, electro-weak and spin excitations would have same mass and this does not seem to make sense. Thus it seems that p-adic thermodynamics giving extremely small probability for all large n excitations must be correct for elementary particles at least. Again there is however loophole involved. Low energy hadron physics corresponds to non- perturbative QCD like theory and one might wonder whether these exotic states of Super Virasoro algebra could become important at low hadron momentum transfers and whether some kind of phase transition from the dominance of the ordinary Super Virasoro representations to that of exotic Super Virasoro representations might take place. Amazingly, this hypothesis predicts the mass of pion and Regge slope correctly as fundamental constants of Nature [K64].

12.7.3 Could Exotic P-Adic Counterparts Of Elementary Particles Be Relevant For Living Systems?

Previous arguments do not exclude the appearance of $n\ mod\ p^k = 0$ p-adic states. Also their zero energy pairs could appear as real states. If the couplings of these excitations obey the conservation of L_0 charge (conformal weight), the states in class m couple only to the states in same class or to $n = 0$ massless states and therefore these particles could probably emit and absorb ordinary $n = 0$ elementary particles. The possibility of pair creation seems to be excluded (it would require that antiparticles have negative spectrum of L_0, which looks peculiar). If this is true then $m = 1$ states are not be created in ordinary elementary particle reactions. It must be emphasized that the matrix elements for emission of exotic states could be small for other reasons: for instance, because the conformal weights of states involved differ so much.

An interesting possibility is that $m > 1$ excitations of known elementary particles could be present in macroscopic length scales.

1. For hadrons $m = 2$ excitations correspond by Uncertainty Principle to the length scale $L_e(k = 2 \times 107) \sim .4$ meters whereas for electron one has length scale $L_e(k = 2 \times 127) \sim 10^7$ meters. The corresponding time scale is .1 seconds, which is the fundamental time scale of brain consciousness defining the duration of psychological moment. This time scale is crucial in the TGD based model of memetic code. The model derives from a model of abstraction process leading to a hierarchy of "genetic codes" labelled by Mersenne numbers: $M(n) = M_{M(n-1)}$. $M_7 = 127$ corresponds to genetic code and M_{127}, which is the next level of the hierarchy, corresponds to the memetic code.

2. For $m = 2$ excitations of Z^0 and W (also other states could be present) the corresponding length scale is $L_e(k = 2 \times 89 = 178) \sim 10^{-4}$ meters, which is $2^{4.5}$ times larger than the p-adic length scale $L_e(k = 169)$ associated with neutrinos. Is this a pure accident or could it be that there are exotic Z^0 bosons in cell length scale and that this explains the primary condensation level of neutrinos? In this picture it would be perhaps easier to understand also why classical Z^0 fields appear dominantly above cell length scale as required by the arguments based on the smallness of parity breaking effects. It should be mentioned that $k = 178$ corresponds to the size of the largest neurons.

The super astronomical degeneracy $D \sim exp(p)$, $p = M_{89}$ (!) associated with these excitations plus Negentropy Maximization Principle could make biosystems with size larger that the critical size of 10^{-4} meters something quite special, to put it very mildly! The same argument applies to the $p = M_{127}$ associated with the memetic code. The p-adic length scale nearest to $L_e(178)$ corresponds to the secondary condensation level for the $m = 2$ particles. It is $k = 179$ and in fact forms twin prime with $k = 181$. As a rule, twin primes in bio-systems seem to be associated with two-layered structures and this particular twin prime corresponds to ocular dominance columns, the largest known two-layered structure in the cortex (in fact this twin prime is the first one in the series of three twin primes $(179, 181)$, $(191, 193)$, $(197, 199)$!).

This raises the question whether the physics based explanation for the huge qualitative and quantitative differences in the behavior of higher primates and more primitive life forms could be based on the huge entanglement entropy resources provided by these exotic particles? It seems that this question becomes more or less obsolete with the realization that the immense super-symplectic almost-degeneracies for the massless states of super-conformal representations explain very naturally the huge information resources of biosystems without need to introduce exotic representations.

One can end up to the similar speculations via a different route by starting from the TGD based reduction of the notion of potential energy to space-time topology (potential energy unlike kinetic energy does not allow any visualization in standard physics and thus remains a fictive concept).

1. In TGD framework the sign of energy depends on the time orientation of the space-time sheet and can be negative. Topological field quanta of negative energy represent negative energy virtual particles. The generation of negative potential energy corresponds to the emission of negative energy virtual bosons condensing on larger space-time sheets and in this manner one can understand potential energy as the total energy emitted by particle in form of low energy topological field quanta condensed on larger space-time sheets. In particular, the huge energy densities in strong gravitational fields of early cosmology result via the emission of negative energy virtual gravitons: only in this manner one can understand in TGD framework how conservation of energy can be consistent with gravitational interaction. For instance, gravitational redshift, which in GRT means non-conservation of energy, results in TGD framework from the absorption of negative energy virtual gravitons.

2. An objection against this interpretation is provided by long range classical Z^0 fields: attractive classical Z^0 potential energy should also correspond to topological field quanta of negative energy at larger space-time sheets. This is certainly possible. These topological field quanta cannot however correspond to the ordinary quanta of Z^0 field which are extremely massive and propagate only over range of order 10^{-17} meters. Thus the correspondence *quanta↔topological quanta* seems to fail.

3. There is however a loophole allowed by p-adic mathematics. As already noticed, the secondary almost massless excitations $n \ mod \ p = 0$ of Super Virasoro algebra have mass of order $m(CP_2)/p$ and possess huge exponential degeneracy of states characteristic for the Super Virasoro algebra. For $p = M_{89} = 2^{89} - 1$ the mass of these excitations is of order $m \sim m_W 2^{-89/2} \sim 10^{-2}$ eV, which happens to be rather near to the thermal energy associated with the room temperature, which is the critical temperature for the higher forms of biological life. The corresponding length scale is by Uncertainty Principle 10^{-4} meters and would represent the range of the Z^0 forces based on the exchange of the secondary quanta. Thus the exchange of these quanta between nuclei and neutrinos could be an essential element of what it is to be biosystem. These excitations having huge ground state degeneracy could also provide a quantum level description for the huge degeneracy of states certainly characteristic for biosystems. This degeneracy might also explain dynamically why neutrinos topologically condense on cell length scale.

4. A further objection is that classical Z^0 force seems to be not restricted to biological length scales but is present also in the planetary length scales. This objection can be circumvented too. Higher secondary excitations of Super Virasoro algebra satisfying $n \ mod \ p^3 = 0$ with mass of order $m(CP_2)/p^{3/2}$ should be also present. This mass would correspond to $m \sim 2^{-89} m_W$ and to the length scale of 2×10^9 meters characterizing solar system. The corresponding time scale is 8 seconds, which is also an important length scale in biosystems

as is also the time scale of .1 seconds associated with the second power of $p = M_{127}$, which is the p-adic length scale of electron and characterizes memetic code. This hypothesis is consistent with the idea that ELF em and Z^0 fields give rise to a new form of life, "culture", living in symbiosis with biological life.

5. This would suggest a hierarchy of lifeforms whose intelligence quotient is roughly characterized by the degeneracy of the Super Virasoro states involved and thus by the power and value of the p-adic prime p to which they correspond. Since Mersenne primes are fundamental for elementary particle physics, one expects that the powers of the Mersenne primes M_{89}, M_{107} and $M127$ should label the most important higher lifeforms. M_{89} would give rise to two higher levels already discussed whereas M_{127} gives rise to the menetic code. The $n\ mod\ p^2 = 0$ excitations associated with M_{107}, the Mersenne prime characterizing hadrons, would correspond to the length scale of about 25 meters and time scale of order 10^{-7} seconds. $n\ mod\ p^3 = 0$ excitations associated with M_{107} would in turn correspond to the time scale of 10^9 seconds, or 30 years in more natural units: this is of the same order as human life span!

6. A further observation of possible relevance is that if Super Algebra representation has vanishing conformal vacuum weight, the subalgebra consisting of generators having conformal weights n proportional to p^m forms sub-algebra of entire Super algebra. Thus the exotic states correspond to sub-algebra of Super Virasoro and become therefore even more interesting in light of fractality suggesting strongly hierarchical breaking of supersymmetry to subalgebras of Super Virasoro algebra isomorphic with the entire algebra.

Because of their physical properties MEs provide excellent candidate for a model of mind-like space-time sheets and one can assign to the light-like boundaries of MEs super-symplectic representations defining quantum holograms. Thus MEs could carry also exotic p-adic Super Virasoro representations but as already noticed, they are not needed in order to understand the information sources associated with living matter.

Chapter 13

Homeostasis as self-organized quantum criticality?

13.1 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 [I94] and manage to stay near criticality, which means SOQC. Note that the self-organized criticality (SOC) is generalized to SOQC.

Topological Geometrodynamics (TGD) [?] [K4, K7] is a 43 year old proposal for a unification of fundamental interactions. Zero energy ontology (ZEO) [L62] 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 [L57] predicting both arrows of time. Could ZEO make SOQC possible as well?

13.1.1 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 [I12] and HSP90 [I10] have ATPase at their end whereas HSP60 has ATP binding site [I11]. 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 [I8, I3, I83, I103] are expressed when the temperature of the organism is reduced /increased from the physiological temperature. CSPs possess cold-shock domains [I2] 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 [I2] mentions Escherichia Coli as an example. When the temperature is reduced from 37 °C to 10 °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 [I106, I29, I37, I73, I103]. 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 [I29] and as ATPAses [I65, I85].

   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 [I85]. 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?

13.1.2 The notion of quantum criticality

The basic postulate of quantum TGD is that the TGD Universe is quantum critical [K4, K7] [L24, L23]. 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 [A14] cusp catastrophe corresponds to a V-shaped line, whose vertex is a critical

point whereas butterflly 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 [A14]. 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 [K4] [**?**, **?**, **?**, **?**].

4. Criticality in living systems is a special case of criticality - and as the work of Kauffman [I94] suggests - of quantum crticality 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 [L31, L32] 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 $L(k = 167) = 2^{(167-151)/2}L(151) = 2.5$ μ 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 μm, .64 μ, and .8 μm.

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 [D30] give support [L35]? 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 [L17, L18]: 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.

13.1.3 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 [L62]. 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 $h_{eff} = h_{gr}$ [L44], where h_{gr} is gravitational Planck constant introduced originally by Nottale [E6], 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.

13.2 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.

13.2.1 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.

$$\begin{array}{cccccc} X/Y & SP & MB(SP) & BM & MB(BM) & E \\ SP & * & \mathbf{H} & * & * & * \\ MB(SP) & \mathbf{H} & * & \mathbf{H} & * & \mathbf{H} \\ BM & * & \mathbf{H} & * & \mathbf{L} & * \\ MB(BM) & * & * & \mathbf{L} & * & * \\ E & * & \mathbf{H} & * & * & * \end{array} \tag{13.2.1}$$

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 $\rightarrow$ 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 μm 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 $E_{max} = .084$ 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 [L17, L18] 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 $L(167) = 2.5$ μm. 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 lengh 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.

13.2.2 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 possoble 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 μm: note that the sizes of most animal and plant cells are oin the rage of 10-100 μm. For the wavelength distribution the wavelength for the maximum is roughly 7 μm. CSPs and HSPs consist of about 100-1000 amino acids or so. Length would be in the range .1-1 μm. 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.

13.2.3 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 [I94] 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.

13.2.4 $\Delta C_p > 0$ 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 [I85] 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 $h_eff = h$ 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 [I85] 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.

13.2.5 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 resourses 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 [I29, I79, I73]: 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 [I79] . 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 [I31, I78, I55] discussed from TGD point view in [L7]. "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 [I51]. 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.

13.2.6 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" [J26] (`https://cutt.ly/YJUYx0n`)

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 [L80].

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 [L47].

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 [L72].]

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 wake-up 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!

13.3 Speculative mechanisms explaining some biological observations

In the sequel some speculative applications will be considered.

13.3.1 Obesity, failing diets, and SPs

The effects of diets on HSP expression and activation have recently been studied, see for instance [I39, I91, I99, I96]. 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 [I85] 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 [I40]. HSP60 is known to be associated with obesity [I99]. 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 [I90] expression is considerably higher in obesity without metabolic syndrome but lower in obesity with metabolic syndrome [I96]. 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 [I59]. 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 [D60]: the finding is discussed from the point of view of ZEO in [L60].

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$\rightarrow$ 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.

13.3.2 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 [I35]: 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 [I60]: the TGD based model is discussed in [L61]. 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 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 [L31, L32]. In the recent view of quantum TGD [L71], both notions reduce to physics as number theory vision, which relies on $M^8 - H$ duality [L58, L59] and is complementary to the physics as geometry vision.

Zero energy ontology (ZEO) [L52] [K122] 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) [L52, L64] [K122] causal diamond

(CD) is defined as cartesian product $CD \times CP_2$. Often I use CD to refer just to $CD \times CP_2$ since CP_2 factor is relevant from the point of view of ZEO.

Fig. 2. Future and past light-cones M^4_+ and M^4_-. Causal diamonds (CD) are defined as their intersections. `http://tgdtheory.fi/appfigures/futurepast.jpg`

Fig. 3. Causal diamond (CD) is highly analogous to Penrose diagram but simpler. `http://tgdtheory.fi/appfigures/penrose.jpg`

A rather recent discovery was that CP_2 is the only compact 4-manifold with Euclidian signature of metric allowing twistor space with Kähler structure. M^4 is in turn is the only 4-D space with Minkowskian signature of metric allowing twistor space with Kähler structure [A21] so that $H = M^4 \times CP_2$ is twistorially unique.

One can loosely say that quantum states in a given sector of "world of classical worlds" (WCW) are superpositions of space-time surfaces inside CDs and that positive and negative energy parts of zero energy states are localized and past and future boundaries of CDs. CDs form a hierarchy. One can have CDs within CDs and CDs can also overlap. The size of CD is characterized by the proper time distance between its two tips. One can perform both translations and also Lorentz boosts of CD leaving either boundary invariant. Therefore one can assign to CDs a moduli space and speak about wave function in this moduli space.

In number theoretic approach it is natural to restrict the allowed Lorentz boosts to some discrete subgroup of Lorentz group and also the distances between the tips of CDs to multiples of CP_2 radius defined by the length of its geodesic. Therefore the moduli space of CDs discretizes. The quantization of cosmic recession velocities for which there are indications, could relate to this quantization.

A-2.1 Basic facts about CP_2

CP_2 as a four-manifold is very special. The following arguments demonstrate that it codes for the symmetries of standard models via its isometries and holonomies.

CP_2 as a manifold

CP_2, the complex projective space of two complex dimensions, is obtained by identifying the points of complex 3-space C^3 under the projective equivalence

$$(z^1, z^2, z^3) \equiv \lambda(z^1, z^2, z^3) \ . \tag{A-2.1}$$

Here λ is any non-zero complex number. Note that CP_2 can be also regarded as the coset space $SU(3)/U(2)$. The pair z^i/z^j for fixed j and $z^i \neq 0$ defines a complex coordinate chart for CP_2. As j runs from 1 to 3 one obtains an atlas of three coordinate charts covering CP_2, the charts being holomorphically related to each other (e.g. CP_2 is a complex manifold). The points $z^3 \neq 0$ form a subset of CP_2 homoeomorphic to R^4 and the points with $z^3 = 0$ a set homeomorphic to S^2. Therefore CP_2 is obtained by "adding the 2-sphere at infinity to R^4".

Besides the standard complex coordinates $\xi^i = z^i/z^3$, $i = 1, 2$ the coordinates of Eguchi and Freund [A15] will be used and their relation to the complex coordinates is given by

$$\begin{aligned} \xi^1 &= z + it \ , \\ \xi^2 &= x + iy \ . \end{aligned} \tag{A-2.2}$$

These are related to the "spherical coordinates" via the equations

$$\begin{aligned} \xi^1 &= rexp(i\frac{(\Psi + \Phi)}{2})cos(\frac{\Theta}{2}) \ , \\ \xi^2 &= rexp(i\frac{(\Psi - \Phi)}{2})sin(\frac{\Theta}{2}) \ . \end{aligned} \tag{A-2.3}$$

The ranges of the variables r, Θ, Φ, Ψ are $[0, \infty], [0, \pi], [0, 4\pi], [0, 2\pi]$ respectively.

Considered as a real four-manifold CP_2 is compact and simply connected, with Euler number Euler number 3, Pontryagin number 3 and second $b = 1$.

Fig. 4. CP_2 as manifold. `http://tgdtheory.fi/appfigures/cp2.jpg`

Metric and Kähler structure of CP_2

In order to obtain a natural metric for CP_2, observe that CP_2 can be thought of as a set of the orbits of the isometries $z^i \rightarrow exp(i\alpha)z^i$ on the sphere S^5: $\sum z^i\bar{z}^i = R^2$. The metric of CP_2 is obtained by projecting the metric of S^5 orthogonally to the orbits of the isometries. Therefore the distance between the points of CP_2 is that between the representative orbits on S^5.

The line element has the following form in the complex coordinates

$$ds^2 = g_{a\bar{b}} d\xi^a d\bar{\xi}^b \ , \tag{A-2.4}$$

where the Hermitian, in fact Kähler metric $g_{a\bar{b}}$ is defined by

$$g_{a\bar{b}} = R^2 \partial_a \partial_{\bar{b}} K \ , \tag{A-2.5}$$

where the function K, Kähler function, is defined as

$$\begin{aligned} K &= log(F) \ , \\ F &= 1 + r^2 \ . \end{aligned} \tag{A-2.6}$$

The Kähler function for S^2 has the same form. It gives the S^2 metric $dzd\bar{z}/(1+r^2)^2$ related to its standard form in spherical coordinates by the coordinate transformation $(r, \phi) = (tan(\theta/2), \phi)$.

The representation of the CP_2 metric is deducible from S^5 metric is obtained by putting the angle coordinate of a geodesic sphere constant in it and is given

$$\frac{ds^2}{R^2} = \frac{(dr^2 + r^2\sigma_3^2)}{F^2} + \frac{r^2(\sigma_1^2 + \sigma_2^2)}{F} \ , \tag{A-2.7}$$

where the quantities σ_i are defined as

$$\begin{aligned} r^2\sigma_1 &= Im(\xi^1 d\xi^2 - \xi^2 d\xi^1) \ , \\ r^2\sigma_2 &= -Re(\xi^1 d\xi^2 - \xi^2 d\xi^1) \ , \\ r^2\sigma_3 &= -Im(\xi^1 d\bar{\xi}^1 + \xi^2 d\bar{\xi}^2) \ . \end{aligned} \tag{A-2.8}$$

R denotes the radius of the geodesic circle of CP_2. The vierbein forms, which satisfy the defining relation

$$s_{kl} = R^2 \sum_A e_k^A e_l^A \ , \tag{A-2.9}$$

are given by

$$\begin{aligned} e^0 &= \tfrac{dr}{F} \ , \quad e^1 = \tfrac{r\sigma_1}{\sqrt{F}} \ , \\ e^2 &= \tfrac{r\sigma_2}{\sqrt{F}} \ , \quad e^3 = \tfrac{r\sigma_3}{F} \ . \end{aligned} \tag{A-2.10}$$

The explicit representations of vierbein vectors are given by

$$\begin{array}{lllllll} e^0 & = & \frac{dr}{F} \ , & e^1 & = & \frac{r(sin\Theta cos\Psi d\Phi + sin\Psi d\Theta)}{2\sqrt{F}} & , \\ e^2 & = & \frac{r(sin\Theta sin\Psi d\Phi - cos\Psi d\Theta)}{2\sqrt{F}} \ , & e^3 & = & \frac{r(d\Psi + cos\Theta d\Phi)}{2F} & . \end{array} \tag{A-2.11}$$

The explicit representation of the line element is given by the expression

$$ds^2/R^2 = \frac{dr^2}{F^2} + \frac{r^2}{4F^2}(d\Psi + cos\Theta d\Phi)^2 + \frac{r^2}{4F}(d\Theta^2 + sin^2\Theta d\Phi^2) \ . \tag{A-2.12}$$

From this expression one finds that at coordinate infinity $r = \infty$ line element reduces to $\frac{r^2}{4F}(d\Theta^2 + sin^2\Theta d\Phi^2)$ of S^2 meaning that 3-sphere degenerates metrically to 2-sphere and one can say that CP_2 is obtained by adding to R^4 a 2-sphere at infinity.

The vierbein connection satisfying the defining relation

$$de^A = -V^A_B \wedge e^B \ , \tag{A-2.13}$$

is given by

$$\begin{array}{llllll} V_{01} & = & -\frac{e^1}{r} \ , & V_{23} & = & \frac{e^1}{r} \ , \\ V_{02} & = & -\frac{e^2}{r} \ , & V_{31} & = & \frac{e^2}{r} \ , \\ V_{03} & = & (r - \frac{1}{r})e^3 \ , & V_{12} & = & (2r + \frac{1}{r})e^3 \ . \end{array} \tag{A-2.14}$$

The representation of the covariantly constant curvature tensor is given by

$$\begin{array}{llllll} R_{01} & = & e^0 \wedge e^1 - e^2 \wedge e^3 \ , & R_{23} & = & e^0 \wedge e^1 - e^2 \wedge e^3 \ , \\ R_{02} & = & e^0 \wedge e^2 - e^3 \wedge e^1 \ , & R_{31} & = & -e^0 \wedge e^2 + e^3 \wedge e^1 \ , \\ R_{03} & = & 4e^0 \wedge e^3 + 2e^1 \wedge e^2 \ , & R_{12} & = & 2e^0 \wedge e^3 + 4e^1 \wedge e^2 \ . \end{array} \tag{A-2.15}$$

Metric defines a real, covariantly constant, and therefore closed 2-form J

$$J = -is_{a\bar{b}} d\xi^a d\bar{\xi}^b \ , \tag{A-2.16}$$

the so called Kähler form. Kähler form J defines in CP_2 a symplectic structure because it satisfies the condition

$$J^k_{\ r} J^{rl} = -s^{kl} \ . \tag{A-2.17}$$

The condition states that J and g give representations of real unit and imaginary units related by the formula $i^2 = -1$.

Kähler form is expressible locally in terms of Kähler gauge potential

$$J = dB \ , \tag{A-2.18}$$

where B is the so called Kähler potential, which is not defined globally since J describes homological magnetic monopole.

$dJ = ddB = 0$ gives the topological half of Maxwell equations (vanishing of magnetic charges and Faraday's induction law) and self-duality $*J = J$ reduces the remaining equations to $dJ = 0$. Hence the Kähler form can be regarded as a curvature form of a $U(1)$ gauge potential B carrying a magnetic charge of unit $1/2g$ (g denotes the gauge coupling).

The magnetic flux of J through a 2-surface in CP_2 is proportional to its homology equivalence class, which is integer valued. The explicit representations of J and B are given by

$$\begin{aligned} B &= 2re^3 \ , \\ J &= 2(e^0 \wedge e^3 + e^1 \wedge e^2) = \frac{r}{F^2} dr \wedge (d\Psi + cos\Theta d\Phi) + \frac{r^2}{2F} sin\Theta d\Theta \wedge d\Phi \ . \end{aligned} \tag{A-2.19}$$

The vierbein curvature form and Kähler form are covariantly constant and have in the complex coordinates only components of type (1, 1).

Useful coordinates for CP_2 are the so called canonical (or symplectic or Darboux) coordinates in which the Kähler potential and Kähler form have very simple expressions

$$\begin{aligned} B &= \sum_{k=1,2} P_k dQ_k \ , \\ J &= \sum_{k=1,2} dP_k \wedge dQ_k \ . \end{aligned} \tag{A-2.20}$$

The relationship of the canonical coordinates to the "spherical" coordinates is given by the equations

$$\begin{aligned} P_1 &= -\frac{1}{1+r^2} \ , \\ P_2 &= -\frac{r^2 cos\Theta}{2(1+r^2)} \ , \\ Q_1 &= \Psi \ , \\ Q_2 &= \Phi \ . \end{aligned} \tag{A-2.21}$$

Spinors In CP_2

CP_2 doesn't allow spinor structure in the conventional sense [A9]. However, the coupling of the spinors to a half odd multiple of the Kähler potential leads to a respectable spinor structure. Because the delicacies associated with the spinor structure of CP_2 play a fundamental role in TGD, the arguments of Hawking are repeated here.

To see how the space can fail to have an ordinary spinor structure consider the parallel transport of the vierbein in a simply connected space M. The parallel propagation around a closed curve with a base point x leads to a rotated vierbein at x: $e^A = R^A_B e^B$ and one can associate to each closed path an element of $SO(4)$.

Consider now a one-parameter family of closed curves $\gamma(v) : v \in (0,1)$ with the same base point x and $\gamma(0)$ and $\gamma(1)$ trivial paths. Clearly these paths define a sphere S^2 in M and the element $R^A_B(v)$ defines a closed path in $SO(4)$. When the sphere S^2 is contractible to a point e.g., homologically trivial, the path in $SO(4)$ is also contractible to a point and therefore represents a trivial element of the homotopy group $\Pi_1(SO(4)) = Z_2$.

For a homologically nontrivial 2-surface S^2 the associated path in $SO(4)$ can be homotopically nontrivial and therefore corresponds to a nonclosed path in the covering group Spin(4) (leading from the matrix 1 to -1 in the matrix representation). Assume this is the case.

Assume now that the space allows spinor structure. Then one can parallel propagate also spinors and by the above construction associate a closed path of Spin(4) to the surface S^2. Now, however this path corresponds to a lift of the corresponding $SO(4)$ path and cannot be closed. Thus one ends up with a contradiction.

From the preceding argument it is clear that one could compensate the non-allowed -1-factor associated with the parallel transport of the spinor around the sphere S^2 by coupling it to a gauge potential in such a way that in the parallel transport the gauge potential introduces a compensating -1-factor. For a $U(1)$ gauge potential this factor is given by the exponential

$exp(i2\Phi)$, where Φ is the magnetic flux through the surface. This factor has the value -1 provided the $U(1)$ potential carries half odd multiple of Dirac charge $1/2g$. In case of CP_2 the required gauge potential is half odd multiple of the Kähler potential B defined previously. In the case of $M^4 \times CP_2$ one can in addition couple the spinor components with different chiralities independently to an odd multiple of $B/2$.

Geodesic sub-manifolds of CP_2

Geodesic sub-manifolds are defined as sub-manifolds having common geodesic lines with the embedding space. As a consequence the second fundamental form of the geodesic manifold vanishes, which means that the tangent vectors h^k_α (understood as vectors of H) are covariantly constant quantities with respect to the covariant derivative taking into account that the tangent vectors are vectors both with respect to H and X^4.

In [A33] a general characterization of the geodesic sub-manifolds for an arbitrary symmetric space G/H is given. Geodesic sub-manifolds are in 1-1-correspondence with the so called Lie triple systems of the Lie-algebra g of the group G. The Lie triple system t is defined as a subspace of g characterized by the closedness property with respect to double commutation

$$[X,[Y,Z]] \in t \ \text{ for } \ X,Y,Z \in t \ . \tag{A-2.22}$$

$SU(3)$ allows, besides geodesic lines, two nonequivalent (not isometry related) geodesic spheres. This is understood by observing that $SU(3)$ allows two nonequivalent $SU(2)$ algebras corresponding to subgroups $SO(3)$ (orthogonal 3×3 matrices) and the usual isospin group $SU(2)$. By taking any subset of two generators from these algebras, one obtains a Lie triple system and by exponentiating this system, one obtains a 2-dimensional geodesic sub-manifold of CP_2.

Standard representatives for the geodesic spheres of CP_2 are given by the equations

$$S^2_I \ : \ \xi^1 = \bar{\xi}^2 \ \text{ or equivalently } \ (\Theta = \pi/2, \Psi = 0) \ ,$$

$$S^2_{II} \ : \ \xi^1 = \xi^2 \ \text{ or equivalently } \ (\Theta = \pi/2, \Phi = 0) \ .$$

The non-equivalence of these sub-manifolds is clear from the fact that isometries act as holomorphic transformations in CP_2. The vanishing of the second fundamental form is also easy to verify. The first geodesic manifold is homologically trivial: in fact, the induced Kähler form vanishes identically for S^2_I. S^2_{II} is homologically nontrivial and the flux of the Kähler form gives its homology equivalence class.

A-2.2 CP_2 geometry and Standard Model symmetries

Identification of the electro-weak couplings

The delicacies of the spinor structure of CP_2 make it a unique candidate for space S. First, the coupling of the spinors to the $U(1)$ gauge potential defined by the Kähler structure provides the missing $U(1)$ factor in the gauge group. Secondly, it is possible to couple different H-chiralities independently to a half odd multiple of the Kähler potential. Thus the hopes of obtaining a correct spectrum for the electromagnetic charge are considerable. In the following it will be demonstrated that the couplings of the induced spinor connection are indeed those of the GWS model [B25] and in particular that the right handed neutrinos decouple completely from the electro-weak interactions.

To begin with, recall that the space H allows to define three different chiralities for spinors. Spinors with fixed H-chirality $e = \pm 1$, CP_2-chirality l, r and M^4-chirality L, R are defined by the condition

$$\begin{aligned} \Gamma\Psi &= e\Psi \ , \\ e &= \pm 1 \ , \end{aligned} \tag{A-2.23}$$

where Γ denotes the matrix $\Gamma_9 = \gamma_5 \otimes \gamma_5$, $1 \otimes \gamma_5$ and $\gamma_5 \otimes 1$ respectively. Clearly, for a fixed H-chirality CP_2- and M^4-chiralities are correlated.

The spinors with H-chirality $e = \pm 1$ can be identified as quark and lepton like spinors respectively. The separate conservation of baryon and lepton numbers can be understood as a consequence of generalized chiral invariance if this identification is accepted. For the spinors with a definite H-chirality one can identify the vielbein group of CP_2 as the electro-weak group: $SO(4)$ having as its covering group $SU(2)_L \times SU(2)_R$.

The covariant derivatives are defined by the spinorial connection

$$A = V + \frac{B}{2}(n_+ 1_+ + n_- 1_-) \ . \tag{A-2.24}$$

Here V and B denote the projections of the vielbein and Kähler gauge potentials respectively and $1_{+(-)}$ projects to the spinor H-chirality $+(-)$. The integers $n_\pm$ are odd from the requirement of a respectable spinor structure.

The explicit representation of the vielbein connection V and of B are given by the equations

$$\begin{array}{lllllll} V_{01} & = & -\frac{e^1}{r} & , & V_{23} & = & \frac{e^1}{r} \ , \\ V_{02} & = & -\frac{e^2}{r} & , & V_{31} & = & \frac{e^2}{r} \ , \\ V_{03} & = & (r-\frac{1}{r})e^3 & , & V_{12} & = & (2r+\frac{1}{r})e^3 \ , \end{array} \tag{A-2.25}$$

and

$$B = 2re^3 \ , \tag{A-2.26}$$

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

$$A_{ch} = 2V_{23}I_L^1 + 2V_{13}I_L^2 \ , \tag{A-2.27}$$

where one have defined

$$\begin{aligned} I_L^1 &= \frac{(\Sigma_{01} - \Sigma_{23})}{2} \ , \\ I_L^2 &= \frac{(\Sigma_{02} - \Sigma_{13})}{2} \ . \end{aligned} \tag{A-2.28}$$

A_{ch} is clearly left handed so that one can perform the identification of the gauge potential as

$$W^\pm = \frac{2(e^1 \pm ie^2)}{r} \ , \tag{A-2.29}$$

where $W^\pm$ denotes the charged intermediate vector boson.

The covariantly constant curvature tensor is given by

$$\begin{array}{l} R_{01} = -R_{23} = e^0 \wedge e^1 - e^2 \wedge e^3 \ , \\ R_{02} = -R_{31} = e^0 \wedge e^2 - e^3 \wedge e^1 \ , \\ R_{03} = 4e^0 \wedge e^3 + 2e^1 \wedge e^2 \ , \\ R_{12} = 2e^0 \wedge e^3 + 4e^1 \wedge e^2 \ . \end{array} \tag{A-2.30}$$

The charged part of the curvature tensor is left handed.

This is to be compared with the Weyl tensor, which defines a representation of quaternionic imaginary units.

$$
\begin{array}{l}
W_{03} = W_{12} \equiv 2I_3 = 2(e^0 \wedge e^3 + e^1 \wedge e^2) \ , \\
W_{01} = W_{23} \equiv I_1 = -e^0 \wedge e^1 - e^2 \wedge e^3 \ , \\
W_{02} = W_{31} \equiv I_2 = -e^0 \wedge e^2 - e^3 \wedge e^1 \ .
\end{array}
\tag{A-2.31}
$$

The charged part of the Weyl tensor is right-handed and that the relative sign of the two terms in the curvature tensor and Weyl tensor are opposite.

Consider next the identification of the neutral gauge bosons γ and Z^0 as appropriate linear combinations of the two functionally independent quantities

$$
\begin{array}{lll}
X & = & re^3 \ , \\
Y & = & \frac{e^3}{r} \ ,
\end{array}
\tag{A-2.32}
$$

appearing in the neutral part of the spinor connection. We show first that the mere requirement that photon couples vectorially implies the basic coupling structure of the GWS model leaving only the value of Weinberg angle undetermined.

To begin with let us define

$$
\begin{array}{lll}
\bar{\gamma} & = & aX + bY \ , \\
\bar{Z}^0 & = & cX + dY \ ,
\end{array}
\tag{A-2.33}
$$

where the normalization condition

$$ad - bc = 1 \ ,$$

is satisfied. The physical fields γ and Z^0 are related to $\bar{\gamma}$ and $\bar{Z}^0$ by simple normalization factors.

Expressing the neutral part of the spinor connection in term of these fields one obtains

$$
\begin{array}{lll}
A_{nc} & = & [(c+d)2\Sigma_{03} + (2d-c)2\Sigma_{12} + d(n_+1_+ + n_-1_-)]\bar{\gamma} \\
 & + & [(a-b)2\Sigma_{03} + (a-2b)2\Sigma_{12} - b(n_+1_+ + n_-1_-)]\bar{Z}^0 \ .
\end{array}
\tag{A-2.34}
$$

Identifying Σ_{12} and $\Sigma_{03} = 1 \times \gamma_5 \Sigma_{12}$ as vectorial and axial Lie-algebra generators, respectively, the requirement that γ couples vectorially leads to the condition

$$
c = -d \ .
\tag{A-2.35}
$$

Using this result plus previous equations, one obtains for the neutral part of the connection the expression

$$
A_{nc} = \gamma Q_{em} + Z^0(I_L^3 - sin^2\theta_W Q_{em}) \ .
\tag{A-2.36}
$$

Here the electromagnetic charge Q_{em} and the weak isospin are defined by

$$
\begin{array}{lll}
Q_{em} & = & \Sigma^{12} + \frac{(n_+1_+ + n_-1_-)}{6} \ , \\
I_L^3 & = & \frac{(\Sigma^{12} - \Sigma^{03})}{2} \ .
\end{array}
\tag{A-2.37}
$$

The fields γ and Z^0 are defined via the relations

$$
\begin{array}{lll}
\gamma & = & 6d\bar{\gamma} = \frac{6}{(a+b)}(aX + bY) \ , \\
Z^0 & = & 4(a+b)\bar{Z}^0 = 4(X - Y) \ .
\end{array}
\tag{A-2.38}
$$

The value of the Weinberg angle is given by

$$sin^2\theta_W = \frac{3b}{2(a+b)} \ , \tag{A-2.39}$$

and is not fixed completely. Observe that right handed neutrinos decouple completely from the electro-weak interactions.

The determination of the value of the Weinberg angle is a dynamical problem. The original approach was based on the assumption that it makes sense to talk about electroweak action defined at fundamental level and introduce a symmetry breaking by adding an additional term proportional to Kähler action. The recent view is that Kähler action plus volume term defines the fundamental action.

The Weinberg angle is completely fixed if one requires that the electroweak action contains no cross term of type γZ^0. This leads to a definite value for the Weinberg angle.

One can however add a symmetry breaking term proportional to Kähler action and this changes the value of the Weinberg angle. As a matter fact, color gauge action identifying color gauge field as proportional to $H^A J_{\alpha\beta}$ is proportional to Kähler action. A possible interpretation would be as a sum of electroweak and color gauge interactions.

To evaluate the value of the Weinberg angle one can express the neutral part F_{nc} of the induced gauge field as

$$F_{nc} = 2R_{03}\Sigma^{03} + 2R_{12}\Sigma^{12} + J(n_+1_+ + n_-1_-) \ , \tag{A-2.40}$$

where one has

$$\begin{aligned} R_{03} &= 2(2e^0 \wedge e^3 + e^1 \wedge e^2) \ , \\ R_{12} &= 2(e^0 \wedge e^3 + 2e^1 \wedge e^2) \ , \\ J &= 2(e^0 \wedge e^3 + e^1 \wedge e^2) \ , \end{aligned} \tag{A-2.41}$$

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

$$F_{nc} = \gamma Q_{em} + Z^0(I_L^3 - sin^2\theta_W Q_{em}) \ . \tag{A-2.42}$$

Evaluating the expressions above, one obtains for γ and Z^0 the expressions

$$\begin{aligned} \gamma &= 3J - sin^2\theta_W R_{12} \ , \\ Z^0 &= 2R_{03} \ . \end{aligned} \tag{A-2.43}$$

For the Kähler field one obtains

$$J = \frac{1}{3}(\gamma + sin^2\theta_W Z^0) \ . \tag{A-2.44}$$

Expressing the neutral part of the symmetry broken YM action

$$\begin{aligned} L_{ew} &= L_{sym} + fJ^{\alpha\beta}J_{\alpha\beta} \ , \\ L_{sym} &= \frac{1}{4g^2}Tr(F^{\alpha\beta}F_{\alpha\beta}) \ , \end{aligned} \tag{A-2.45}$$

where the trace is taken in spinor representation, in terms of γ and Z^0 one obtains for the coefficient X of the γZ^0 cross term (this coefficient must vanish) the expression

$$
\begin{aligned}
X &= -\frac{K}{2g^2} + \frac{fp}{18} \ , \\
K &= Tr\left[Q_{em}(I_L^3 - sin^2\theta_W Q_{em})\right] \ ,
\end{aligned}
\tag{A-2.46}
$$

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

$$
K = \sum_i \left[-\frac{(18+2n_i^2)sin^2\theta_W}{9}\right] \ , \tag{A-2.47}
$$

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

$$
sin^2\theta_W = \frac{9\sum_i 1}{(fg^2 + 2\sum_i(18+n_i^2))} \ . \tag{A-2.48}
$$

In the scenario where both leptons and quarks are elementary fermions the value of the Weinberg angle is given by

$$
sin^2\theta_W = \frac{9}{(\frac{fg^2}{2} + 28)} \ . \tag{A-2.49}
$$

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 [B7]. The experimental value at the scale length scale of the electron can be deduced from the ratio of W and Z boson masses as $sin^2\theta_W = 1-(m_W/m_Z)^2 \simeq .22290$. This ratio and also the weak boson masses depend on the length scale.

If one interprets the additional term proportional to J as color action, one could perhaps interpret the value of Weinberg angle as expressing a connection between strong and weak coupling constant evolution. The limit $f \rightarrow 0$ should correspond to an infinite value of color coupling strength and at this limit one would have $sin^2\theta_W = \frac{9}{28}$ for $f/g^2 \rightarrow 0$. This does not make sense since the Weinberg angle is in the standard model much smaller in QCD scale Λ corresponding roughly to pion mass scale. The Weinberg angle is in principle predicted by the p-adic coupling constant evolution fixed by the number theoretical vision of TGD.

One could however have a sum of electroweak action, correction terms changing the value of Weinberg angle, and color action and coupling constant evolution could be understood in terms of the coupling parameters involved.

Electroweak symmetry breaking

One of the hardest challenges in the development of the TGD based view of weak symmetry breaking was the fact that classical field equations allow space-time surfaces with finite but arbitrarily large size. For a fixed space-time surface, the induced gauge fields, including classical weak fields, are long ranged. On the other hand, the large mass for weak bosons would require a short correlation length. How can one understand this together with the fact that a photon has a long correlation length?

In zero energy ontology quantum states are superpositions of space-time surfaces as analogs of almost unique Bohr orbits of particles identified as 3-D surfaces. For some reason the superposition should be such that the quantum averages of weak gauge boson fields vanish below the weak scale whereas the quantum average of electromagnetic fields is non-vanishing.

This is indeed the case.

1. The supersymplectic symmetries form isometries of the world of classical worlds (WCW) and they act in CP_2 degrees of freedom as symplectic transformations leaving the CP_2 symplectic form J invariant and therefore also its contribution to the electromagnetic field since this part is the same for all space-time surfaces in the superposition of space-time surfaces as a representation of supersymplectic isometry group (as a special case a representation of color group).

2. In TGD, color and electroweak symmetries acting as holonomies are not independent and for the $SU(2)_L$ part of induced spinor connection the symplectic transformations induces $SU(2)_L \times U(1)_R$ gauge transformation. This suggests that the quantum expectations of the induced weak fields over the space-time surfaces vanish above the quantum coherence scale. The averages of W and of the left handed part of Z^0 should therefore vanish.

3. $\langle Z^0 \rangle$ should vanish. For $U(1)_R$ part of Z^0, the action of gauge transformation is trivial in gauge theory. Now however the space-time surface changes under symplectic transformations and this could make the average of the right-handed part of Z^0 vanishing. The vanishing of the average of the axial part of the Z^0 is suggested by the partially conserved axial current hypothesis.

One can formulate this picture quantitatively.

1. The electromagnetic field [L76] contains, besides the induced Kähler form, also the induced curvature form R_{12}, which couples vectorially. Conserved vector current hypothesis suggests that the average of R_{12} is non-vanishing. One can express the neutral part of the induced gauge field in terms of induced spinor curvature and Kähler form J as

$$\begin{aligned} R_{03} &= 2(2e^0 \wedge e^3 + e^1 \wedge e^2) = J + 2e^0 \wedge e^3 \quad , \\ J &= 2(e^0 \wedge e^3 + e^1 \wedge e^2) \quad , \\ R_{12} &= 2(e^0 \wedge e^3 + 2e^1 \wedge e^2) = 3J - 2e^0 \wedge e^3 \quad , \end{aligned} \tag{A-2.50}$$

2. The induced fields γ and Z^0 (photon and Z- boson) can be expressed as

$$\begin{aligned} \gamma &= 3J - sin^2\theta_W R_{12} \quad , \\ Z^0 &= 2R_{03} = 2(J + 2e^0 \wedge e^3) \qquad \text{(A-2.51)} \\ & per. \qquad \text{(A-2.52)} \end{aligned}$$

The condition $\langle Z^0 \rangle = 0$ gives $2\langle e^0 \wedge e^3 \rangle = -2J$ and this in turn gives $\langle R_{12} \rangle = 4J$. The average over γ would be

$$\langle \gamma \rangle = (3 - 4sin^2\theta_W)J \quad .$$

For $sin^2\theta_W = 3/4 \; langle\gamma\rangle$ would vanish.

The quantum averages of classical weak fields quite generally vanish. What about correlation functions?

1. One expects that the correlators of classical weak fields as color invariants, and perhaps even symplectic invariants, are non-vanishing below the Compton length since in this kind of situation the points in the correlation function belong to the same 3-surface representing particle, such as hadron.

2. The intuitive picture is that in longer length scales one has disjoint 3-surfaces with a size scale of Compton length. If the states associated with two disjoint 3-surfaces are separately color invariant there are no correlations in color degrees of freedom and correlators reduce to the products of expectations of classical weak fields and vanish. This could also hold when the 3-surfaces are connected by flux tube bonds.

   Below the Compton length weak bosons would thus behave as correlated massless fields. The Compton lengths of weak bosons are proportional to the value of effective Planck constant h_{eff} and in living systems the Compton lengths are proposed to be even of the order of cell size. This would explain the mysterious chiral selection in living systems requiring large parity violation.

3. What about the averages and correlators of color gauge fields? Classical color gauge fields are proportional to the products of Hamiltonians of color isometries induced Kähler form and the expectations of color Hamiltonians give vanishing average above Compton length and therefore vanishing average. Correlators are non-vanishing below the hadron scale. Gluons do not propagate in long scales for the same reason as weak bosons. This is implied by color confinement, which has also classical description in the sense that 3-surfaces have necessarily a finite size.

   A large value of h_{eff} allows colored states even in biological scales below the Compton length since in this kind of situation the points in the correlation function belong to the same 3-surface representing particle, such as dark hadron.

Discrete symmetries

The treatment of discrete symmetries C, P, and T is based on the following requirements:

1. Symmetries must be realized as purely geometric transformations.

2. Transformation properties of the field variables should be essentially the same as in the conventional quantum field theories [B9] .

The action of the reflection P on spinors of is given by

$$\Psi \quad \rightarrow \quad P\Psi = \gamma^0 \otimes \gamma^0 \Psi \ . \tag{A-2.53}$$

in the representation of the gamma matrices for which γ^0 is diagonal. It should be noticed that W and Z^0 bosons break parity symmetry as they should since their charge matrices do not commute with the matrix of P.

The guess that a complex conjugation in CP_2 is associated with T transformation of the physicist turns out to be correct. One can verify by a direct calculation that pure Dirac action is invariant under T realized according to

$$\begin{aligned} m^k &\rightarrow T(M^k) \ , \\ \xi^k &\rightarrow \bar{\xi}^k \ , \\ \Psi &\rightarrow \gamma^1\gamma^3 \otimes 1\Psi \ . \end{aligned} \tag{A-2.54}$$

The operation bearing closest resemblance to the ordinary charge conjugation corresponds geometrically to complex conjugation in CP_2:

$$\begin{aligned} \xi^k &\rightarrow \bar{\xi}^k \ , \\ \Psi &\rightarrow \Psi^\dagger\gamma^2\gamma^0 \otimes 1 \ . \end{aligned} \tag{A-2.55}$$

As one might have expected symmetries CP and T are exact symmetries of the pure Dirac action.

A-3 Induction procedure and many-sheeted space-time

Since the classical gauge fields are closely related in TGD framework, it is not possible to have space-time sheets carrying only single kind of gauge field. For instance, em fields are accompanied by Z^0 fields for extremals of Kähler action.

Classical em fields are always accompanied by Z^0 field and some components of color gauge field. For extremals having homologically non-trivial sphere as a CP_2 projection em and Z^0 fields are the only non-vanishing electroweak gauge fields. For homologically trivial sphere only W fields are non-vanishing. Color rotations does not affect the situation.

For vacuum extremals all electro-weak gauge fields are in general non-vanishing although the net gauge field has U(1) holonomy by 2-dimensionality of the CP_2 projection. Color gauge field has $U(1)$ holonomy for all space-time surfaces and quantum classical correspondence suggest a weak form of color confinement meaning that physical states correspond to color neutral members of color multiplets.

A-3.1 Induction procedure for gauge fields and spinor connection

Induction procedure for gauge potentials and spinor structure is a standard procedure of bundle theory. If one has embedding of some manifold to the base space of a bundle, the bundle structure can be induced so that it has as a base space the imbedded manifold, whose points have as fiber the fiber if embedding space at their image points. In the recent case the embedding of space-time surface to embedding space defines the induction procedure. The induced gauge potentials and gauge fields are projections of the spinor connection of the embedding space to the space-time surface (see `http://tgdtheory.fi/appfigures/induct.jpg`).

Induction procedure makes sense also for the spinor fields of embedding space and one obtains geometrization of both electroweak gauge potentials and of spinors. The new element is induction of gamma matrices which gives their projections at space-time surface.

As a matter fact, the induced gamma matrices cannot appear in the counterpart of massless Dirac equation. To achieve super-symmetry, Dirac action must be replaced with Kähler-Dirac action for which gamma matrices are contractions of the canonical momentum currents of Kähler action with embedding space gamma matrices. Induced gamma matrices in Dirac action would correspond to 4-volume as action.

Fig. 9. Induction of spinor connection and metric as projection to the space-time surface. `http://tgdtheory.fi/appfigures/induct.jpg`.

A-3.2 Induced gauge fields for space-times for which CP_2 projection is a geodesic sphere

If one requires that space-time surface is an extremal of Kähler action and has a 2-dimensional CP_2 projection, only vacuum extremals and space-time surfaces for which CP_2 projection is a geodesic sphere, are allowed. Homologically non-trivial geodesic sphere correspond to vanishing W fields and homologically non-trivial sphere to non-vanishing W fields but vanishing γ and Z^0. This can be verified by explicit examples.

$r=\infty$ surface gives rise to a homologically non-trivial geodesic sphere for which e_0 and e_3 vanish imply the vanishing of W field. For space-time sheets for which CP_2 projection is $r=\infty$ homologically non-trivial geodesic sphere of CP_2 one has

$$\gamma = (\frac{3}{4} - \frac{sin^2(\theta_W)}{2})Z^0 \simeq \frac{5Z^0}{8} \quad .$$

The induced W fields vanish in this case and they vanish also for all geodesic sphere obtained by $SU(3)$ rotation.

$Im(\xi^1) = Im(\xi^2) = 0$ corresponds to homologically trivial geodesic sphere. A more general representative is obtained by using for the phase angles of standard complex CP_2 coordinates constant values. In this case e^1 and e^3 vanish so that the induced em, Z^0, and Kähler fields vanish but induced W fields are non-vanishing. This holds also for surfaces obtained by color rotation. Hence one can say that for non-vacuum extremals with 2-D CP_2 projection color rotations and weak symmetries commute.

A-3.3 Many-sheeted space-time

TGD space-time is many-sheeted: in other words, there are in general several space-sheets which have projection to the same M^4 region. Second manner to say this is that CP_2 coordinates are many-valued functions of M^4 coordinates. The original physical interpretation of many-sheeted space-time time was not correct: it was assumed that single sheet corresponds to GRT space-time and this obviously leads to difficulties since the induced gauge fields are expressible in terms of only four embedding space coordinates.

Fig. 10. Illustration of many-sheeted space-time of TGD. `http://tgdtheory.fi/appfigures/manysheeted.jpg`

Superposition of effects instead of superposition of fields

The first objection against TGD is that superposition is not possible for induced gauge fields and induced metric. The resolution of the problem is that it is effects which need to superpose, not the fields.

Test particle topologically condenses simultaneously to all space-time sheets having a projection to same region of M^4 (that is touches them). The superposition of effects of fields at various space-time sheets replaces the superposition of fields.This is crucial for the understanding also how GRT space-time relates to TGD space-time, which is also in the appendix of this book).

Wormhole contacts

Wormhole contacts are key element of many-sheeted space-time. One does not expect them to be stable unless there is non-trivial Kähler magnetic flux flowing through then so that the throats look like Kähler magnetic monopoles.

Fig. 11. Wormhole contact. `http://tgdtheory.fi/appfigures/wormholecontact.jpg`

Since the flow lines of Kähler magnetic field must be closed this requires the presence of another wormhole contact so that one obtains closed monopole flux tube decomposing to two Minkowskian pieces at the two space-time sheets involved and two wormhole contacts with Euclidian signature of the induced metric. These objects are identified as space-time correlates of elementary particles and are clearly analogous to string like objects.

The relationship between the many-sheeted space-time of TGD and of GRT space-time

The space-time of general relativity is single-sheeted and there is no need to regard it as surface in H although the assumption about representability as vacuum extremal gives very powerful constraints in cosmology and astrophysics and might make sense in simple situations.

The space-time of GRT can be regarded as a long length scale approximation obtained by lumping together the sheets of the many-sheeted space-time to a region of M^4 and providing it with an effective metric obtained as sum of M^4 metric and deviations of the induced metrics of various space-time sheets from M^4 metric. Also induced gauge potentials sum up in the similar manner so that also the gauge fields of gauge theories would not be fundamental fields.

Fig. 12. The superposition of fields is replaced with the superposition of their effects in many-sheeted space-time. `http://tgdtheory.fi/appfigures/fieldsuperpose.jpg`

Space-time surfaces of TGD are considerably simpler objects that the space-times of general relativity and relate to GRT space-time like elementary particles to systems of condensed matter physics. Same can be said about fields since all fields are expressible in terms of embedding space coordinates and their gradients, and general coordinate invariance means that the number of bosonic field degrees is reduced locally to 4. TGD space-time can be said to be a microscopic description whereas GRT space-time a macroscopic description. In TGD complexity of space-time topology replaces the complexity due to large number of fields in quantum field theory.

Topological field quantization and the notion of magnetic body

Topological field quantization also TGD from Maxwell's theory. TGD predicts topological light rays ("massless extremals (MEs)") as space-time sheets carrying waves or arbitrary shape propagating with maximal signal velocity in single direction only and analogous to laser beams and carrying light-like gauge currents in the generi case. There are also magnetic flux quanta and electric flux quanta. The deformations of cosmic strings with 2-D string orbit as M^4 projection gives rise to magnetic flux tubes carrying monopole flux made possible by CP_2 topology allowing homological Kähler magnetic monopoles.

Fig. 13. Topological quantization for magnetic fields replaces magnetic fields with bundles of them defining flux tubes as topological field quanta. `http://tgdtheory.fi/appfigures/field.jpg`

The imbeddability condition for say magnetic field means that the region containing constant magnetic field splits into flux quanta, say tubes and sheets carrying constant magnetic field. Unless one assumes a separate boundary term in Kähler action, boundaries in the usual sense are forbidden except as ends of space-time surfaces at the boundaries of causal diamonds. One obtains typically pairs of sheets glued together along their boundaries giving rise to flux tubes with closed cross section possibly carrying monopole flux.

These kind of flux tubes might make possible magnetic fields in cosmic scales already during primordial period of cosmology since no currents are needed to generate these magnetic fields: cosmic string would be indeed this kind of objects and would dominated during the primordial period. Even superconductors and maybe even ferromagnets could involve this kind of monopole flux tubes.

A-3.4 Embedding space spinors and induced spinors

One can geometrize also fermionic degrees of freedom by inducing the spinor structure of $M^4 \times CP_2$.

CP_2 does not allow spinor structure in the ordinary sense but one can couple the opposite H-chiralities of H-spinors to an $n = 1$ ($n = 3$) integer multiple of Kähler gauge potential to obtain a respectable modified spinor structure. The em charges of resulting spinors are fractional (integer valued) and the interpretation as quarks (leptons) makes sense since the couplings to the induced spinor connection having interpretation in terms electro-weak gauge potential are identical to those assumed in standard model.

The notion of quark color differs from that of standard model.

1. Spinors do not couple to color gauge potential although the identification of color gauge potential as projection of $SU(3)$ Killing vector fields is possible. This coupling must emerge only at the effective gauge theory limit of TGD.

2. Spinor harmonics of embedding space correspond to triality $t = 1$ ($t = 0$) partial waves. The detailed correspondence between color and electroweak quantum numbers is however not correct as such and the interpretation of spinor harmonics of embedding space is as representations for ground states of super-conformal representations. The wormhole pairs associated with physical quarks and leptons must carry also neutrino pair to neutralize weak quantum numbers above the length scale of flux tube (weak scale or Compton length). The total color quantum numbers or these states must be those of standard model. For instance, the color quantum numbers of fundamental left-hand neutrino and lepton can compensate each other for the physical lepton. For fundamental quark-lepton pair they could sum up to those of physical quark.

The well-definedness of em charge is crucial condition.

1. Although the embedding space spinor connection carries W gauge potentials one can say that the embedding space spinor modes have well-defined em charge. One expects that this is true for induced spinor fields inside wormhole contacts with 4-D CP_2 projection and Euclidian signature of the induced metric.

2. The situation is not the same for the modes of induced spinor fields inside Minkowskian region and one must require that the CP_2 projection of the regions carrying induced spinor field is such that the induced W fields and above weak scale also the induced Z^0 fields vanish in order to avoid large parity breaking effects. This condition forces the CP_2 projection to be 2-dimensional. For a generic Minkowskian space-time region this is achieved only if the

spinor modes are localized at 2-D surfaces of space-time surface - string world sheets and possibly also partonic 2-surfaces.

3. Also the Kähler-Dirac gamma matrices appearing in the modified Dirac equation must vanish in the directions normal to the 2-D surface in order that Kähler-Dirac equation can be satisfied. This does not seem plausible for space-time regions with 4-D CP_2 projection.

4. One can thus say that strings emerge from TGD in Minkowskian space-time regions. In particular, elementary particles are accompanied by a pair of fermionic strings at the opposite space-time sheets and connecting wormhole contacts. Quite generally, fundamental fermions would propagate at the boundaries of string world sheets as massless particles and wormhole contacts would define the stringy vertices of generalized Feynman diagrams. One obtains geometrized diagrammatics, which brings looks like a combination of stringy and Feynman diagrammatics.

5. This is what happens in the the generic situation. Cosmic strings could serve as examples about surfaces with 2-D CP_2 projection and carrying only em fields and allowing delocalization of spinor modes to the entire space-time surfaces.

A-3.5 About induced gauge fields

In the following the induced gauge fields are studied for general space-time surface without assuming the preferred extremal property (Bohr orbit property). Therefore the following arguments are somewhat obsolete in their generality.

Space-times with vanishing em, Z^0, or Kähler fields

The following considerations apply to a more general situation in which the homologically trivial geodesic sphere and extremal property are not assumed. It must be emphasized that this case is possible in TGD framework only for a vanishing Kähler field.

Using spherical coordinates (r, Θ, Ψ, Φ) for CP_2, the expression of Kähler form reads as

$$\begin{aligned} J &= \frac{r}{F^2} dr \wedge (d\Psi + cos(\Theta)d\Phi) + \frac{r^2}{2F} sin(\Theta) d\Theta \wedge d\Phi \ , \\ F &= 1 + r^2 \ . \end{aligned} \tag{A-3.1}$$

The general expression of electromagnetic field reads as

$$\begin{aligned} F_{em} &= (3+2p)\frac{r}{F^2} dr \wedge (d\Psi + cos(\Theta)d\Phi) + (3+p)\frac{r^2}{2F} sin(\Theta) d\Theta \wedge d\Phi \ , \\ p &= sin^2(\Theta_W) \ , \end{aligned} \tag{A-3.2}$$

where Θ_W denotes Weinberg angle.

1. The vanishing of the electromagnetic fields is guaranteed, when the conditions

$$\begin{aligned} \Psi &= k\Phi \ , \\ (3+2p)\frac{1}{r^2 F}(d(r^2)/d\Theta)(k + cos(\Theta)) &+ (3+p) sin(\Theta) = 0 \ , \end{aligned} \tag{A-3.3}$$

hold true. The conditions imply that CP_2 projection of the electromagnetically neutral space-time is 2-dimensional. Solving the differential equation one obtains

$$
\begin{aligned}
r &= \sqrt{\frac{X}{1-X}} \ , \\
X &= D\left[|\frac{k+u}{C}|\right]^{\epsilon} \ , \\
u &\equiv cos(\Theta) \ , \ C = k + cos(\Theta_0) \ , \ D = \frac{r_0^2}{1+r_0^2} \ , \ \epsilon = \frac{3+p}{3+2p} \ ,
\end{aligned}
\tag{A-3.4}
$$

where C and D are integration constants. $0 \leq X \leq 1$ is required by the reality of r. $r = 0$ would correspond to $X = 0$ giving $u = -k$ achieved only for $|k| \leq 1$ and $r = \infty$ to $X = 1$ giving $|u+k| = [(1+r_0^2)/r_0^2)]^{(3+2p)/(3+p)}$ achieved only for

$$
sign(u+k) \times [\frac{1+r_0^2}{r_0^2}]^{\frac{3+2p}{3+p}} \leq k+1 \ ,
$$

where $sign(x)$ denotes the sign of x.

The expressions for Kähler form and Z^0 field are given by

$$
\begin{aligned}
J &= -\frac{p}{3+2p} X du \wedge d\Phi \ , \\
Z^0 &= -\frac{6}{p} J \ .
\end{aligned}
\tag{A-3.5}
$$

The components of the electromagnetic field generated by varying vacuum parameters are proportional to the components of the Kähler field: in particular, the magnetic field is parallel to the Kähler magnetic field. The generation of a long range Z^0 vacuum field is a purely TGD based feature not encountered in the standard gauge theories.

2. The vanishing of Z^0 fields is achieved by the replacement of the parameter ϵ with $\epsilon = 1/2$ as becomes clear by considering the condition stating that Z^0 field vanishes identically. Also the relationship $F_{em} = 3J = -\frac{3}{4}\frac{r^2}{F} du \wedge d\Phi$ is useful.

3. The vanishing Kähler field corresponds to $\epsilon = 1, p = 0$ in the formula for em neutral space-times. In this case classical em and Z^0 fields are proportional to each other:

$$
\begin{aligned}
Z^0 &= 2e^0 \wedge e^3 = \frac{r}{F^2}(k+u)\frac{\partial r}{\partial u} du \wedge d\Phi = (k+u) du \wedge d\Phi \ , \\
r &= \sqrt{\frac{X}{1-X}} \ , \ X = D|k+u| \ , \\
\gamma &= -\frac{p}{2} Z^0 \ .
\end{aligned}
\tag{A-3.6}
$$

For a vanishing value of Weinberg angle ($p = 0$) em field vanishes and only Z^0 field remains as a long range gauge field. Vacuum extremals for which long range Z^0 field vanishes but em field is non-vanishing are not possible.

The effective form of CP_2 metric for surfaces with 2-dimensional CP_2 projection

The effective form of the CP_2 metric for a space-time having vanishing em,Z^0, or Kähler field is of practical value in the case of vacuum extremals and is given by

$$\begin{aligned}
ds^2_{eff} &= (s_{rr}(\frac{dr}{d\Theta})^2 + s_{\Theta\Theta})d\Theta^2 + (s_{\Phi\Phi} + 2ks_{\Phi\Psi})d\Phi^2 = \frac{R^2}{4}[s^{eff}_{\Theta\Theta}d\Theta^2 + s^{eff}_{\Phi\Phi}d\Phi^2] \ , \\
s^{eff}_{\Theta\Theta} &= X \times \left[\frac{\epsilon^2(1-u^2)}{(k+u)^2} \times \frac{1}{1-X} + 1 - X\right] \ , \\
s^{eff}_{\Phi\Phi} &= X \times \left[(1-X)(k+u)^2 + 1 - u^2\right] \ ,
\end{aligned} \tag{A-3.7}$$

and is useful in the construction of vacuum embedding of, say Schwartchild metric.

Topological quantum numbers

Space-times for which either em, Z^0, or Kähler field vanishes decompose into regions characterized by six vacuum parameters: two of these quantum numbers (ω_1 and ω_2) are frequency type parameters, two (k_1 and k_2) are wave vector like quantum numbers, two of the quantum numbers (n_1 and n_2) are integers. The parameters ω_i and n_i will be referred as electric and magnetic quantum numbers. The existence of these quantum numbers is not a feature of these solutions alone but represents a much more general phenomenon differentiating in a clear cut manner between TGD and Maxwell's electrodynamics.

The simplest manner to avoid surface Kähler charges and discontinuities or infinities in the derivatives of CP_2 coordinates on the common boundary of two neighboring regions with different vacuum quantum numbers is topological field quantization, 3-space decomposes into disjoint topological field quanta, 3-surfaces having outer boundaries with possibly macroscopic size.

Under rather general conditions the coordinates Ψ and Φ can be written in the form

$$\begin{aligned}
\Psi &= \omega_2 m^0 + k_2 m^3 + n_2\phi + \text{Fourier expansion} \ , \\
\Phi &= \omega_1 m^0 + k_1 m^3 + n_1\phi + \text{Fourier expansion} \ .
\end{aligned} \tag{A-3.8}$$

m^0,m^3 and ϕ denote the coordinate variables of the cylindrical M^4 coordinates) so that one has $k = \omega_2/\omega_1 = n_2/n_1 = k_2/k_1$. The regions of the space-time surface with given values of the vacuum parameters ω_i,k_i and n_i and m and C are bounded by the surfaces at which space-time surface becomes ill-defined, say by $r > 0$ or $r < \infty$ surfaces.

The space-time surface decomposes into regions characterized by different values of the vacuum parameters r_0 and Θ_0. At $r = \infty$ surfaces n_2,ω_2 and m can change since all values of Ψ correspond to the same point of CP_2: at $r = 0$ surfaces also n_1 and ω_1 can change since all values of Φ correspond to same point of CP_2, too. If $r = 0$ or $r = \infty$ is not in the allowed range space-time surface develops a boundary.

This implies what might be called topological quantization since in general it is not possible to find a smooth global embedding for, say a constant magnetic field. Although global embedding exists it decomposes into regions with different values of the vacuum parameters and the coordinate u in general possesses discontinuous derivative at $r = 0$ and $r = \infty$ surfaces. A possible manner to avoid edges of space-time is to allow field quantization so that 3-space (and field) decomposes into disjoint quanta, which can be regarded as structurally stable units a 3-space (and of the gauge field). This doesn't exclude partial join along boundaries for neighboring field quanta provided some additional conditions guaranteeing the absence of edges are satisfied.

For instance, the vanishing of the electromagnetic fields implies that the condition

$$\Omega \equiv \frac{\omega_2}{n_2} - \frac{\omega_1}{n_1} = 0 \ , \tag{A-3.9}$$

is satisfied. In particular, the ratio ω_2/ω_1 is rational number for the electromagnetically neutral regions of space-time surface. The change of the parameter n_1 and n_2 (ω_1 and ω_2) in general generates magnetic field and therefore these integers will be referred to as magnetic (electric) quantum numbers.

A-4 The relationship of TGD to QFT and string models

The recent view of the relationship of TGD to QFT and string models has developed slowly during years and it seems that in a certain sense TGD means a return to roots: instead of QFT like description involving path integral one would have wave mechanics for 3-surfaces.

A-4.1 TGD as a generalization of wave mechanism obtained by replacing point-like particles with 3-surfaces

The first vision of TGD was as a generalization of quantum field theory (string models) obtained by replacing pointlike particles (strings) as fundamental objects with 3-surfaces.

The later work has revealed that TGD could be seen as a generalization of the wave mechanism based on the replacement of a point-like particle with 3-D surface. This is due to holography implied by general coordinate invariance. The definition of the metric of the "world of classical worlds" (WCW) must assign a unique or at least almost unique space-time surface to a given 3-surface. This 4-surface is analogous to Bohr orbit so that also Bohr orbitology becomes an exact part of quantum physics. The failure of strict determinism forces to replace 3-surfaces with 4-surfaces and this leads to zero energy ontology (ZEO) in which quantum states are superpositions of space-time surfaces [K46, K30, K88] [L65, L71].

Fig. 5. TGD replaces point-like particles with 3-surfaces. `http://tgdtheory.fi/appfigures/particletgd.jpg`

A-4.2 Extension of superconformal invariance

The fact that light-like 3-surfaces are effectively metrically 2-dimensional and thus possess generalization of 2-dimensional conformal symmetries with light-like radial coordinate defining the analog of second complex coordinate suggests that this generalization could work and extend the super-conformal symmetries to their 4-D analogs.

The boundary $\delta M^4_+ = S^2 \times R_+$- of 4-D light-cone M^4_+ is also metrically 2-dimensional and allows extended conformal invariance. Also the group of isometries of light-cone boundary and of light-like 3-surfaces is infinite-dimensional since the conformal scalings of S^2 can be compensated by S^2-local scaling of the light-like radial coordinate of R_+. These simple facts mean that 4-dimensional Minkowski space and 4-dimensional space-time surfaces are in a completely unique position as far as symmetries are considered.

In fact, this leads to a generalization of the Kac-Moody type symmetries of string models. $\delta M^4_+ \times CP_2$ allows huge supersymplectic symmetries for which the radial light-like coordinate of δM^4_+ plays the role of complex string coordinate in string models. These symmetries are assumed to act as isometries of WCW.

A-4.3 String-like objects and strings

String like objects obtained as deformations of cosmic strings $X^2 \times Y^2$, where X^2 is minimal surface in M^4 and Y^2 a holomorphic surface of CP_2 are fundamental extremals of Kähler action having string world sheet as M^4 projections. Cosmic strings dominate the primordial cosmology of the TGD Universe and the inflationary period corresponds to the transition to radiation dominated cosmology for which space-time sheets with 4-D M^4 projection dominate.

Also genuine string-like objects emerge from TGD. The conditions that the em charge of modes of induces spinor fields is well-defined requires in the generic case the localization of the modes at 2-D surfaces -string world sheets and possibly also partonic 2-surfaces. This in Minkowskian space-time regions.

Fig. 6. Well-definedness of em charge forces the localization of induced spinor modes to 2-D surfaces in generic situations in Minkowskian regions of space-time surface. `http://tgdtheory.fi/appfigures/fermistring.jpg`

A-4.4 TGD view of elementary particles

The TGD based view about elementary particles has two key aspects.

1. The space-time correlates of elementary particles are identified as pairs of wormhole contacts with Euclidean signature of metric and having 4-D CP_2 projection. Their throats behave effectively as Kähler magnetic monopoles so that wormhole throats must be connected by Kähler magnetic flux tubes with monopole flux so that closed flux tubes are obtained.

2. At the level of H Fermion number is carried by the modes of the induced spinor field. In space-time regions with Minkowski signature the modes are localized at string world sheets connecting the wormhole contacts.

Fig. 7. TGD view about elementary particles. a) Particle orbit corresponds to a 4-D generalization of a world line or b) with its light-like 3-D boundary (holography). c) Particle world lines have Euclidean signature of the induced metric. d) They can be identified as wormhole contacts. e) The throats of wormhole contacts carry effective Kähler magnetic charges so that wormhole contacts must appear as pairs in order to obtain closed flux tubes. f) Wormhole contacts are accompanied by fermionic strings connecting the throats at the same sheet: the strings do not extend inside the wormhole contacts. `http://tgdtheory.fi/appfigures/elparticletgd.jpg`

Particle interactions involve both stringy and QFT aspects.

1. The boundaries of string world sheets correspond to fundamental fermions. This gives rise to massless propagator lines in generalized Feynman diagrammatics. One can speak of "long" string connecting wormhole contacts and having a hadronic string as a physical counterpart. Long strings should be distinguished from wormhole contacts which due to their super-conformal invariance behave like "short" strings with length scale given by CP_2 size, which is 10^4 times longer than Planck scale characterizing strings in string models.

2. Wormhole contact defines basic stringy interaction vertex for fermion-fermion scattering. The propagator is essentially the inverse of the superconformal scaling generator L_0. Wormhole contacts containing fermion and antifermion at its opposite throats behave like virtual bosons so that one has BFF type vertices typically.

3. In topological sense one has 3-vertices serving as generalizations of 3-vertices of Feynman diagrams. In these vertices 4-D "lines" of generalized Feynman diagrams meet along their 3-D ends. One obtains also the analogs of stringy diagrams but stringy vertices do not have the usual interpretation in terms of particle decays but in terms of propagation of particles along two different routes.

Fig. 8. a) TGD analogs of Feynman and string diagrammatics at the level of space-time topology. b) The 4-D analogs of both string diagrams and QFT diagrams appear but the interpretation of the analogs stringy diagrams is different. `http://tgdtheory.fi/appfigures/tgdgraphs.jpg`

A-5 About the selection of the action defining the Kähler function of the "world of classical worlds" (WCW)

The proposal is that space-time surfaces correspond to preferred extremals of some action principle, being analogous to Bohr orbits, so that they are almost deterministic. The action for the preferred extremal would define the Kähler function of WCW [K46, K88].

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 [L33] [L65, L66, L67] generalizes the notion of induction to the level of twistor fields and leads to a proposal that the action is obtained by dimensional reduction of the action having as its preferred extremals the counterpart of twistor space of the space-time surface identified as 6-D surface in the product $T(M^4) \times T(CP_2)$ twistor spaces of $T(M^4)$ and $T(CP_2)$

of M^4 and CP_2. Only M^4 and CP_2 allow a twistor space with Kähler structure [A21] so that TGD would be unique. Dimensional reduction is forced by the condition that the 6-surface has S^2-bundle structure characterizing twistor spaces and the base space would be the space-time surface.

1. Dimensional reduction of 6-D Kähler action implies that at the space-time level the fundamental action can be identified as the sum of Kähler action and volume term (cosmological constant). Other choices of the action do not look natural in this picture although they would have the same preferred extremals.

2. Preferred extremals are proposed to correspond to minimal surfaces with singularities such that they are also extremals of 4-D Kähler action outside the singularities. The physical analogue are soap films spanned by frames and one can localize the violation of the strict determinism and of strict holography to the frames.

3. The preferred extremal property is realized as the holomorphicity characterizing string world sheets, which generalizes to the 4-D situation. This in turn implies that the preferred extremals are the same for any general coordinate invariant action defined on the induced gauge fields and induced metric apart from possible extremals with vanishing CP_2 Kähler action.

   For instance, 4-D Kähler action and Weyl action as the sum of the tensor squares of the components of the Weyl tensor of CP_2 representing quaternionic imaginary units constructed from the Weyl tensor of CP_2 as an analog of gauge field would have the same preferred extremals and only the definition of Kähler function and therefore Kähler metric of WCW would change. One can even consider the possibility that the volume term in the 4-D action could be assigned to the tensor square of the induced metric representing a quaternionic or octonionic real unit.

Action principle does not seem to be unique. On the other hand, the WCW Kähler form and metric should be unique since its existence requires maximal isometries.

Unique action is not the only way to achieve this. One cannot exclude the possibility that the Kähler gauge potential of WCW in the complex coordinates of WCW differs only by a complex gradient of a holomorphic function for different actions so that they would give the same Kähler form for WCW. This gradient is induced by a symplectic transformation of WCW inducing a U(1) gauge transformation. The Kähler metric is the same if the symplectic transformation is an isometry.

Symplectic transformations of WCW could give rise to inequivalent representations of the theory in terms of action at space-time level. Maybe the length scale dependent coupling parameters of an effective action could be interpreted in terms of a choice of WCW Kähler function, which maximally simplifies the computations at a given scale.

1. The 6-D analogues of electroweak action and color action reducing to Kähler action in 4-D case exist. The 6-D analog of Weyl action based on the tensor representation of quaternionic imaginary units does not however exist. One could however consider the possibility that only the base space of twistor space $T(M^4)$ and $T(CP_2)$ have quaternionic structure.

2. Kähler action has a huge vacuum degeneracy, which clearly distinguishes it from other actions. The presence of the volume term removes this degeneracy. However, for minimal surfaces having CP_2 projections, which are Lagrangian manifolds and therefore have a vanishing induced Kähler form, would be preferred extremals according to the proposed definition. For these 4-surfaces, the existence of the generalized complex structure is dubious.

   For the electroweak action, the terms corresponding to charged weak bosons eliminate these extremals and one could argue that electroweak action or its sum with the analogue of color action, also proportional Kähler action, defines the more plausible choice. Interestingly, also the neutral part of electroweak action is proportional to Kähler action.

Twistor lift strongly suggests that also M^4 has the analog of Kähler structure. M^8 must be complexified by adding a commuting imaginary unit i. In the E^8 subspace, the Kähler structure of E^4 is defined in the standard sense and it is proposed that this generalizes to M^4 allowing also generalization of the quaternionic structure. M^4 Kähler structure violates Lorentz invariance but could be realized at the level of moduli space of these structures.

The minimal possibility is that the M^4 Kähler form vanishes: one can have a different representation of the Kähler gauge potential for it obtained as generalization of symplectic transformations acting non-trivially in M^4. The recent picture about the second quantization of spinors of $M^4 \times CP_2$ assumes however non-trivial Kähler structure in M^4.

A-5.2 Two paradoxes

TGD view leads to two apparent paradoxes.

1. If the preferred extremals satisfy 4-D generalization of holomorphicity, a very large set of actions gives rise to the same preferred extremals unless there are some additional conditions restricting the number of preferred extremals for a given action.

2. WCW metric has an infinite number of zero modes, which appear as parameters of the metric but do not contribute to the line element. The induced Kähler form depends on these degrees of freedom. The existence of the Kähler metric requires maximal isometries, which suggests that the Kähler metric is uniquely fixed apart from a conformal scaling factor Ω depending on zero modes. This cannot be true: galaxy and elementary particle cannot correspond to the same Kähler metric.

Number theoretical vision and the hierarchy of inclusions of HFFs associated with supersymplectic algebra actings as isometries of WcW provide equivalent realizations of the measurement resolution. This solves these paradoxes and predicts that WCW decomposes into sectors for which Kähler metrics of WCW differ in a natural way.

The hierarchy subalgebras of supersymplectic algebra implies the decomposition of WCW into sectors with different actions

Supersymplectic algebra of $\delta M^4_+ \times CP_2$ is assumed to act as isometries of WCW [L71]. 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 [L71] 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 [L71] predicts a hierarchy with levels labelled by the degrees $n(P)$ of rational polynomials P and corresponding extensions of rationals characterized by Galois groups and by ramified primes defining p-adic length scales.

These sequences allow us to imagine several discrete coupling constant evolutions realized at the level H in terms of action whose coupling parameters depend on the number theoretic parameters.

1. Coupling constant evolution with respect to $n(P)$

The first coupling constant evolution would be with respect to $n(P)$.

1. The coupling constants characterizing action could depend on the degree $n(P)$ of the polynomial defining the space-time region by M^8-H duality. The complexity of the space-time surface would increase with $n(P)$ and new degrees of freedom would emerge as the number of the rational coefficients of P.

2. This coupling constant evolution could naturally correspond to that assignable to the inclusion hierarchy of hyperfinite factors of type II_1 (HFFs). I have indeed proposed [L71] that the degree $n(P)$ equals to the number $n(braid)$ of braids assignable to HFF for which super symplectic algebra subalgebra $A_{n(SS)}$ with radial conformal weights coming as $n(SS)$-multiples of those of entire algebra A. One would have $n(P)=n(braid)=n(SS)$. The number of dynamical degrees of freedom increases with n which just as it increases with $n(P)$ and $n(SS)$.

3. The actions related to different values of $n(P)=n(braid)=n(SS)$ cannot define the same Kähler metric since the number of allowed space-time surfaces depends on $n(SS)$.

   WCW could decompose to sub-WCWs corresponding to different actions, a kind of theory space. These theories would not be equivalent. A possible interpretation would be as a hierarchy of effective field theories.

4. Hierarchies of composite polynomials define sequences of polynomials with increasing values of $n(P)$ such that the order of a polynomial at a given level is divided by those at the lower levels. The proposal is that the inclusion sequences of extensions are realized at quantum level as inclusion hierarchies of hyperfinite factors of type II_1.

   A given inclusion hierarchy corresponds to a sequence $n(SS)_i$ such that $n(SS)_i$ divides $n(SS)_{i+1}$. Therefore the degree of the composite polynomials increases very rapidly. The values of $n(SS)_i$ can be chosen to be primes and these primes correspond to the degrees of so called prime polynomials [L68] 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 [K60, K61]). 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 [L68], 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 [L68], 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 [L68].

3. p-Adic length scale hypothesis [L72] 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 [L71] 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 $\delta M^4_+ \times CP_2$ [K46, K30]. 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 [L70].

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 [K64, K56, K27]. The fusion of the various p-adic physics leads to what I call adelic physics [L31, L32]. Later the hypothesis about hierarchy of Planck constants labelling phases of ordinary matter behaving like dark matter emerged [K33, K34, K35, K35].

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 [L58, L59] 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 [L68, L70]. 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 [L33] giving rise to an action which is sum of the Kähler action and volume term. The preferred extremals would be minimal surfaces analogous to soap films spanned by frames. Outside frames they would be simultaneous extremals of the Kähler action, which requires a generalization of the holomorphy characterizing string world sheets.

In the following only p-adic numbers and hierarchy of Planck constants will be discussed.

A-6.1 p-Adic numbers and TGD

p-Adic number fields

p-Adic numbers (p is prime: 2, 3, 5, ...) can be regarded as a completion of the rational numbers using a norm, which is different from the ordinary norm of real numbers [A8]. p-Adic numbers are representable as power expansion of the prime number p of form

$$x = \sum_{k\geq k_0} x(k)p^k,\ x(k) = 0, ..., p-1\ . \tag{A-6.1}$$

The norm of a p-adic number is given by

$$|x| = p^{-k_0(x)} . \quad \text{(A-6.2)}$$

Here $k_0(x)$ is the lowest power in the expansion of the p-adic number. The norm differs drastically from the norm of the ordinary real numbers since it depends on the lowest pinary digit of the p-adic number only. Arbitrarily high powers in the expansion are possible since the norm of the p-adic number is finite also for numbers, which are infinite with respect to the ordinary norm. A convenient representation for p-adic numbers is in the form

$$x = p^{k_0}\varepsilon(x) , \quad \text{(A-6.3)}$$

where $\varepsilon(x) = k + ...$ with $0 < k < p$, is p-adic number with unit norm and analogous to the phase factor $exp(i\phi)$ of a complex number.

The distance function $d(x,y) = |x-y|_p$ defined by the p-adic norm possesses a very general property called ultra-metricity:

$$d(x,z) \leq max\{d(x,y), d(y,z)\} . \quad \text{(A-6.4)}$$

The properties of the distance function make it possible to decompose R_p into a union of disjoint sets using the criterion that x and y belong to same class if the distance between x and y satisfies the condition

$$d(x,y) \leq D . \quad \text{(A-6.5)}$$

This division of the metric space into classes has following properties:

1. Distances between the members of two different classes X and Y do not depend on the choice of points x and y inside classes. One can therefore speak about distance function between classes.

2. Distances of points x and y inside single class are smaller than distances between different classes.

3. Classes form a hierarchical tree.

Notice that the concept of the ultra-metricity emerged in physics from the models for spin glasses and is believed to have also applications in biology [B21]. 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 $I : R_p \rightarrow R_+$ from p-adic numbers to non-negative real numbers given by the "pinary" expansion of the real number for $x \in R$ and $y \in R_p$ this correspondence reads

$$\begin{aligned} y &= \sum_{k>N} y_k p^k \rightarrow x = \sum_{k<N} y_k p^{-k} , \\ y_k &\in \{0,1,..,p-1\} . \end{aligned} \quad \text{(A-6.6)}$$

This map is continuous as one easily finds out. There is however a little difficulty associated with the definition of the inverse map since the pinary expansion like also decimal expansion is not unique ($1 = 0.999...$) for the real numbers x, which allow pinary expansion with finite number of pinary digits

$$\begin{aligned} x &= \sum_{k=N_0}^{N} x_k p^{-k} \ , \\ x &= \sum_{k=N_0}^{N-1} x_k p^{-k} + (x_N - 1)p^{-N} + (p-1)p^{-N-1} \sum_{k=0,..} p^{-k} \ . \end{aligned} \tag{A-6.7}$$

The p-adic images associated with these expansions are different

$$\begin{aligned} y_1 &= \sum_{k=N_0}^{N} x_k p^{k} \ , \\ y_2 &= \sum_{k=N_0}^{N-1} x_k p^{k} + (x_N - 1)p^{N} + (p-1)p^{N+1} \sum_{k=0,..} p^{k} \\ &= y_1 + (x_N - 1)p^N - p^{N+1} \ , \end{aligned} \tag{A-6.8}$$

so that the inverse map is either two-valued for p-adic numbers having expansion with finite pinary digits or single valued and discontinuous and non-surjective if one makes pinary expansion unique by choosing the one with finite pinary digits. The finite pinary digit expansion is a natural choice since in the numerical work one always must use a pinary cutoff on the real axis.

2. The topology induced by canonical identification

The topology induced by the canonical identification in the set of positive real numbers differs from the ordinary topology. The difference is easily understood by interpreting the p-adic norm as a norm in the set of the real numbers. The norm is constant in each interval $[p^k, p^{k+1})$ (see **Fig. A-6.1**) and is equal to the usual real norm at the points $x = p^k$: the usual linear norm is replaced with a piecewise constant norm. This means that p-adic topology is coarser than the usual real topology and the higher the value of p is, the coarser the resulting topology is above a given length scale. This hierarchical ordering of the p-adic topologies will be a central feature as far as the proposed applications of the p-adic numbers are considered.

Ordinary continuity implies p-adic continuity since the norm induced from the p-adic topology is rougher than the ordinary norm. p-Adic continuity implies ordinary continuity from right as is clear already from the properties of the p-adic norm (the graph of the norm is indeed continuous from right). This feature is one clear signature of the p-adic topology.

Fig. 14. The real norm induced by canonical identification from 2-adic norm. `http://tgdtheory.fi/appfigures/norm.png`

The linear structure of the p-adic numbers induces a corresponding structure in the set of the non-negative real numbers and p-adic linearity in general differs from the ordinary concept of linearity. For example, p-adic sum is equal to real sum only provided the summands have no common pinary digits. Furthermore, the condition $x +_p y < max\{x, y\}$ holds in general for the p-adic sum of the real numbers. p-Adic multiplication is equivalent with the ordinary multiplication only provided that either of the members of the product is power of p. Moreover one has $x \times_p y < x \times y$ in general. The p-Adic negative -1_p associated with p-adic unit 1 is given by $(-1)_p = \sum_k (p-1)p^k$ and defines p-adic negative for each real number x. An interesting possibility is that p-adic linearity might replace the ordinary linearity in some strongly nonlinear systems so these systems would look simple in the p-adic topology.

These results suggest that canonical identification is involved with some deeper mathematical structure. The following inequalities hold true:

$$\begin{aligned} (x+y)_R &\leq x_R + y_R \ , \\ |x|_p|y|_R \leq (xy)_R &\leq x_R y_R \ , \end{aligned} \tag{A-6.9}$$

where $|x|_p$ denotes p-adic norm. These inequalities can be generalized to the case of $(R_p)^n$ (a linear vector space over the p-adic numbers).

$$\begin{aligned} (x+y)_R &\leq x_R + y_R \ , \\ |\lambda|_p|y|_R \leq (\lambda y)_R &\leq \lambda_R y_R \ , \end{aligned} \tag{A-6.10}$$

where the norm of the vector $x \in T_p^n$ is defined in some manner. The case of Euclidian space suggests the definition

$$(x_R)^2 = (\sum_n x_n^2)_R \ . \tag{A-6.11}$$

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

$$I_Q(q = p^k \times \frac{r}{s}) = p^k \times \frac{I(r)}{I(s)} \tag{A-6.12}$$

is uniquely defined for rationals, maps rationals to rationals, has also a symmetry under exchange of target and domain. This map reduces to a direct identification of rationals for $0 \leq r < p$ and $0 \leq s < p$. It has turned out that it is this map which most naturally appears in the applications. The map is obviously continuous locally since p-adically small modifications of r and s mean small modifications of the real counterparts.

Canonical identification is in a key role in the successful predictions of the elementary particle masses. The predictions for the light elementary particle masses are within extreme accuracy same for I and I_Q but I_Q is theoretically preferred since the real probabilities obtained from p-adic ones by I_Q sum up to one in p-adic thermodynamics.

4. Generalization of number concept and notion of embedding space

TGD forces an extension of number concept: roughly a fusion of reals and various p-adic number fields along common rationals is in question. This induces a similar fusion of real and p-adic embedding spaces. Since finite p-adic numbers correspond always to non-negative reals n-dimensional space R^n must be covered by 2^n copies of the p-adic variant R_p^n of R^n each of which projects to a copy of R_+^n (four quadrants in the case of plane). The common points of p-adic and real embedding spaces are rational points and most p-adic points are at real infinity.

Real numbers and various algebraic extensions of p-adic number fields are thus glued together along common rationals and also numbers in algebraic extension of rationals whose number belong to the algebraic extension of p-adic numbers. This gives rise to a book like structure with rationals and various algebraic extensions of rationals taking the role of the back of the book. Note that Neper number is exceptional in the sense that it is algebraic number in p-adic number field Q_p satisfying $e^p \ mod \ p = 1$.

Fig. 15. Various number fields combine to form a book like structure. `http://tgdtheory.fi/appfigures/book.jpg`

For a given p-adic space-time sheet most points are literally infinite as real points and the projection to the real embedding space consists of a discrete set of rational points: the interpretation in terms of the unavoidable discreteness of the physical representations of cognition is natural. Purely local p-adic physics implies real p-adic fractality and thus long range correlations for the real space-time surfaces having enough common points with this projection.

p-Adic fractality means that M^4 projections for the rational points of space-time surface X^4 are related by a direct identification whereas CP_2 coordinates of X^4 at these points are related by I, I_Q or some of its variants implying long range correlates for CP_2 coordinates. Since only a discrete set of points are related in this manner, both real and p-adic field equations can be satisfied and there are no problems with symmetries. p-Adic effective topology is expected to be a good approximation only within some length scale range which means infrared and UV cutoffs. Also multi-p-fractality is possible.

The notion of p-adic manifold

The notion of p-adic manifold is needed in order to fuse real physics and various p-adic physics to a larger structure which suggests that real and p-adic number fields should be glued together along common rationals bringing in mind adeles. The notion is problematic because p-adic topology is totally disconnected implying that p-adic balls are either disjoint or nested so that ordinary definition of manifold using p-adic chart maps fails. A cure is suggested to be based on chart maps from p-adics to reals rather than to p-adics (see the appendix of the book)

The chart maps are interpreted as cognitive maps, "thought bubbles".

Fig. 16. The basic idea between p-adic manifold. `http://tgdtheory.fi/appfigures/padmanifold.jpg`

There are some problems.

1. Canonical identification does not respect symmetries since it does not commute with second pinary cutoff so that only a discrete set of rational points is mapped to their real counterparts by chart map arithmetic operations which requires pinary cutoff below which chart map takes rationals to rationals so that commutativity with arithmetics and symmetries is achieved in finite resolution: above the cutoff canonical identification is used

2. Canonical identification is continuous but does not map smooth p-adic surfaces to smooth real surfaces requiring second pinary cutoff so that only a discrete set of rational points is mapped to their real counterparts by chart map requiring completion of the image to smooth preferred extremal of Kähler action so that chart map is not unique in accordance with finite measurement resolution

3. Canonical identification violates general coordinate invariance of chart map: (cognition-induced symmetry breaking) minimized if p-adic manifold structure is induced from that for p-adic embedding space with chart maps to real embedding space and assuming preferred coordinates made possible by isometries of embedding space: one however obtains several inequivalent p-adic manifold structures depending on the choice of coordinates: these cognitive representations are not equivalent.

A-6.2 Hierarchy of Planck constants and dark matter hierarchy

Hierarchy of Planck constants was motivated by the "impossible" quantal effects of ELF em fields on vertebrate cyclotron energies $E = hf = \hbar \times eB/m$ are above thermal energy is possible only if $\hbar$ has value much larger than its standard value. Also Nottale's finding that planetary orbits migh be understood as Bohr orbits for a gigantic gravitational Planck constant.

Hierachy of Planck constant would mean that the values of Planck constant come as integer multiples of ordinary Planck constant: $h_{eff} = n \times h$. The particles at magnetic flux tubes characterized by h_{eff} would correspond to dark matter which would be invisible in the sense that only particle with same value of h_{eff} appear in the same vertex of Feynman diagram.

Hierarchy of Planck constants would be due to the non-determism of the Kähler action predicting huge vacuum degeneracy allowing all space-time surfaces which are sub-manfolds of any $M^4 \times Y^2$, where Y^2 is Lagrangian sub-manifold of CP_2. For agiven Y^2 one obtains new manifolds Y^2 by applying symplectic transformations of CP_2.

Non-determinism would mean that the 3-surface at the ends of causal diamond (CD) can be connected by several space-time surfaces carrying same conserved Kähler charges and having same values of Kähler action. Conformal symmetries defined by Kac-Moody algebra associated with the embedding space isometries could act as gauge transformations and respect the light-likeness property of partonic orbits at which the signature of the induced metric changes from Minkowskian to Euclidian (Minkowskianb space-time region transforms to wormhole contact say). The number of conformal equivalence classes of these surfaces could be finite number n and define discrete physical degree of freedom and one would have $h_{eff} = n \times h$. This degeneracy would mean "second quantization" for the sheets of n-furcation: not only one but several sheets can be realized.

This relates also to quantum criticality postulated to be the basic characteristics of the dynamics of quantum TGD. Quantum criticalities would correspond to an infinite fractal hierarchy of broken conformal symmetries defined by sub-algebras of conformal algebra with conformal weights coming as integer multiples of n. This leads also to connections with quantum criticality and hierarchy of broken conformal symmetries, p-adicity, and negentropic entanglement which by consistency with standard quantum measurement theory would be described in terms of density matrix proportional $n \times n$ identity matrix and being due to unitary entanglement coefficients (typical for quantum computing systems).

Formally the situation could be described by regarding space-time surfaces as surfaces in singular n-fold singular coverings of embedding space. A stronger assumption would be that they are expressible as as products of n_1 -fold covering of M^4 and n_2-fold covering of CP_2 meaning analogy with multi-sheeted Riemann surfaces and that M^4 coordinates are n_1-valued functions and CP_2 coordinates n_2 -valued functions of space-time coordinates for $n = n_1 \times n_2$. These singular coverings of embedding space form a book like structure with singularities of the coverings localizable at the boundaries of causal diamonds defining the back of the book like structure.

Fig. 17. Hierarchy of Planck constants. `http://tgdtheory.fi/appfigures/planckhierarchy.jpg`

A-6.3 $M^8 - H$ duality as it is towards the end of 2021

The view of $M^8 - H$ duality (see Appendix **??**) has changed considerably towards the end 2021 [L65] 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 [L65] 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 [L65] are not needed in the sequel.

The 6-D brane-like special solutions in M^8 are of special interest in the TGD inspired theory of consciousness. They have an M^4 projection which is $E = E_n$ 3-ball. Here E_n is a root of the real polynomial P defining $X^4 \subset M^8_c$ (M^8 is complexified to M^8_c) as a "root" of its octonionic continuation [L58, L59]. 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 $X^4 \subset M^8$ [L48]. 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 [L65]. 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 [L63] 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 [L65]. 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 [L52] [K122].

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 [L52].

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 [L46] in atomic scale can be explained by the same mechanism [L46]. 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 [J13] 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 [L47]. 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 [L49, L80].

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 [L49, L80]. ZEO could also allow understanding of what planned actions - like realizing the experiment under consideration - could be.

1. Second law in the standard sense does not favor - perhaps even not allow - realization of planned actions. ZEO forces a generalization of thermodynamics: dissipation with a non-standard arrow of time for a subsystem would look like self-organization and planned action and its realization.

   Could most if not all planned action be like this - induced by BSFR in the geometric future and only apparently planned? There would be however the experience of planning and realizing induced by the signals from geometric future by a higher level in the hierarchy of conscious entities predicted by TGD! In long time scales we would be realizing our fates or wishes of higher level conscious entities rather than agents with completely free will.

2. The notion of magnetic body (MB) serving as a boss of ordinary matter would be central. MB carries dark matter as $h_{eff} = nh_0$ phases of ordinary matter with n serving as a measure for algebraic complexity of extension of rationals as its dimension and defining a kind of universal IQ. There is a hierarchy of these phases and MBs labelled by extension of rationals and the value of n.

   MBs would form a hierarchy of bosses - a realization for master slave hierarchy. Ordinary matter would be at the bottom and its coherent behavior would be induced from quantum coherence at higher levels. BSFR for higher level MB would give rise to what looks like planned actions and experienced as planned action at the lower levels of hierarchy. One could speak of planned actions inducing a cascade of planned actions in shorter time scales and eventually proceeding to atomic level.

A-8 Some notions relevant to TGD inspired consciousness and quantum biology

Below some notions relevant to TGD inspired theory of consciousness and quantum biology.

A-8.1 The notion of magnetic body

Topological field quantization inspires the notion of field body about which magnetic body is especially important example and plays key role in TGD inspired quantum biology and consciousness theory. This is a crucial departure fromt the Maxwellian view. Magnetic body brings in third level to the description of living system as a system interacting strongly with environment. Magnetic body would serve as an intentional agent using biological body as a motor instrument and sensory receptor. EEG would communicated the information from biological body to magnetic body and Libet's findings from time delays of consciousness support this view.

The following pictures illustrate the notion of magnetic body and its dynamics relevant for quantum biology in TGD Universe.

Fig. 18. Magnetic body associated with dipole field. `http://tgdtheory.fi/appfigures/fluxquant.jpg`

Fig. 19. Illustration of the reconnection by magnetic flux loops. `http://tgdtheory.fi/appfigures/reconnect1.jpg`

Fig. 20. Illustration of the reconnection by flux tubes connecting pairs of molecules. `http://tgdtheory.fi/appfigures/reconect2.jpg`

Fig. 21. Flux tube dynamics. a) Reconnection making possible magnetic body to "recognize" the presence of another magnetic body, b) braiding, knotting and linking of flux tubes making possible topological quantum computation, c) contraction of flux tube in phase transition reducing the value of h_{eff} allowing two molecules to find each other in dense molecular soup. `http://tgdtheory.fi/appfigures/fluxtubedynamics.jpg`

A-8.2 Number theoretic entropy and negentropic entanglement

TGD inspired theory of consciousness relies heavily p-Adic norm allows an to define the notion of Shannon entropy for rational probabilities (and even those in algebraic extension of rationals) by replacing the argument of logarithm of probability with its p-adic norm. The resulting entropy can be negative and the interpretation is that number theoretic entanglement entropy defined by this formula for the p-adic prime minimizing its value serves as a measure for conscious information. This negentropy characterizes two-particle system and has nothing to do with the formal negative negentropy assignable to thermodynamic entropy characterizing single particle. Negentropy Maximization Principle (NMP) implies that number theoretic negentropy increases during evolution by quantum jumps. The condition that NMP is consistent with the standard quantum measurement theory requires that negentropic entanglement has a density matrix proportional to unit matrix so that in 2-particle case the entanglement matrix is unitary.

Fig. 22. Schrödinger cat is neither dead or alive. For negentropic entanglement this state would be stable. `http://tgdtheory.fi/appfigures/cat.jpg`

A-8.3 Life as something residing in the intersection of reality and p-adicities

In TGD inspired theory of consciousness p-adic space-time sheets correspond to space-time correlates for thoughts and intentions. The intersections of real and p-adic preferred extremals consist of points whose coordinates are rational or belong to some extension of rational numbers in preferred embedding space coordinates. They would correspond to the intersection of reality and various p-adicities representing the "mind stuff" of Descartes. There is temptation to assign life to the intersection of realities and p-adicities. The discretization of the chart map assigning to real space-time surface its p-adic counterpart would reflect finite cognitive resolution.

At the level of "world of classical worlds" (WCW) the intersection of reality and various p-adicities would correspond to space-time surfaces (or possibly partonic 2-surfaces) representable in terms of rational functions with polynomial coefficients with are rational or belong to algebraic extension of rationals.

The quantum jump replacing real space-time sheet with p-adic one (vice versa) would correspond to a buildup of cognitive representation (realization of intentional action).

Fig. 23. The quantum jump replacing real space-time surface with corresponding p-adic manifold can be interpreted as formation of though, cognitive representation. Its reversal would correspond to a transformation of intention to action. http://tgdtheory.fi/appfigures/padictoreal.jpg

A-8.4 Sharing of mental images

The 3-surfaces serving as correlates for sub-selves can topologically condense to disjoint large space-time sheets representing selves. These 3-surfaces can also have flux tube connections and this makes possible entanglement of sub-selves, which unentangled in the resolution defined by the size of sub-selves. The interpretation for this negentropic entanglement would be in terms of sharing of mental images. This would mean that contents of consciousness are not completely private as assumed in neuroscience.

Fig. 24. Sharing of mental images by entanglement of subselves made possible by flux tube connections between topologically condensed space-time sheets associated with mental images. http://tgdtheory.fi/appfigures/sharing.jpg

A-8.5 Time mirror mechanism

Zero energy ontology (ZEO) is crucial part of both TGD and TGD inspired consciousness and leads to the understanding of the relationship between geometric time and experience time and how the arrow of psychological time emerges. One of the basic predictions is the possibiity of negative energy signals propagating backwards in geometric time and having the property that entropy basically associated with subjective time grows in reversed direction of geometric time. Negative energy signals inspire time mirror mechanism (see **Fig.** http://tgdtheory.fi/appfigures/timemirror.jpg or **Fig.** 24 in the appendix of this book) providing mechanisms of both memory recall, realization of intentational action initiating action already in geometric past, and remote metabolism. What happens that negative energy signal travels to past and is reflected as positive energy signal and returns to the sender. This process works also in the reverse time direction.

Fig. 25. Zero energy ontology allows time mirror mechanism as a mechanism of memory recall. Essentially “seeing” in time direction is in question. http://tgdtheory.fi/appfigures/timemirror.jpg

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