GENES AND MEMES: PART I

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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 $H = M^4 \times CP_2$ [L94]. 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 [L39, L49](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 [L95].

- 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 [K113, L56].

- 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 [K24, K57] [L90].

- 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 [L92]. 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 [L98].

- 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 [L36, L37] 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 [L97]. 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 [L82], 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 [A11]. I have proposed [K49, K27, K111, K86, L95] 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 [K113, L56] 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 [L93]. 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 [L76, L77] 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 [L98].

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 [L91]. 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.

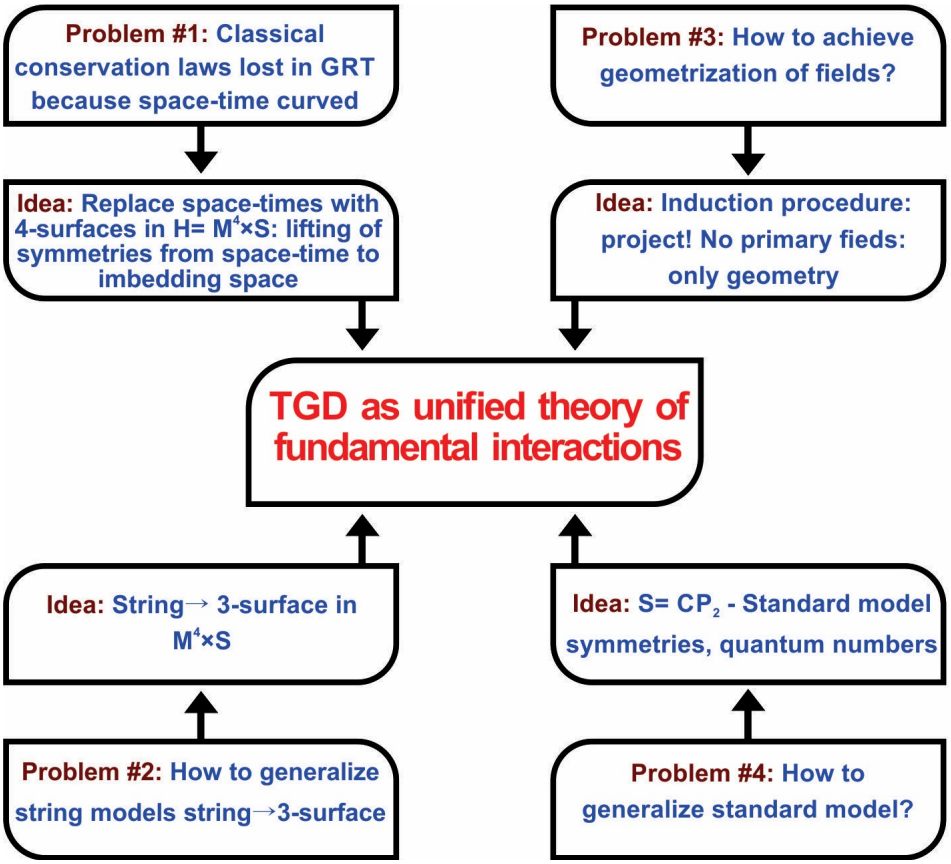


Figure 1: The problems leading to TGD as their solution.

- 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.

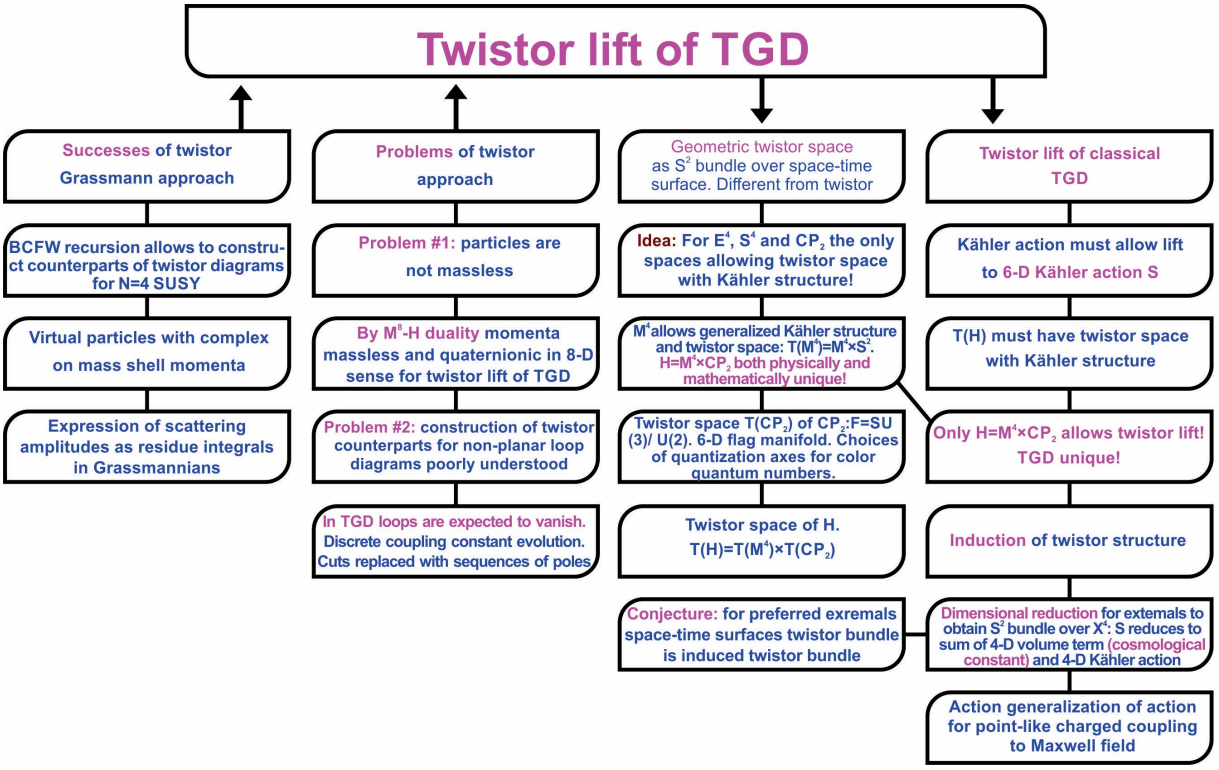


Figure 2: Twistor lift

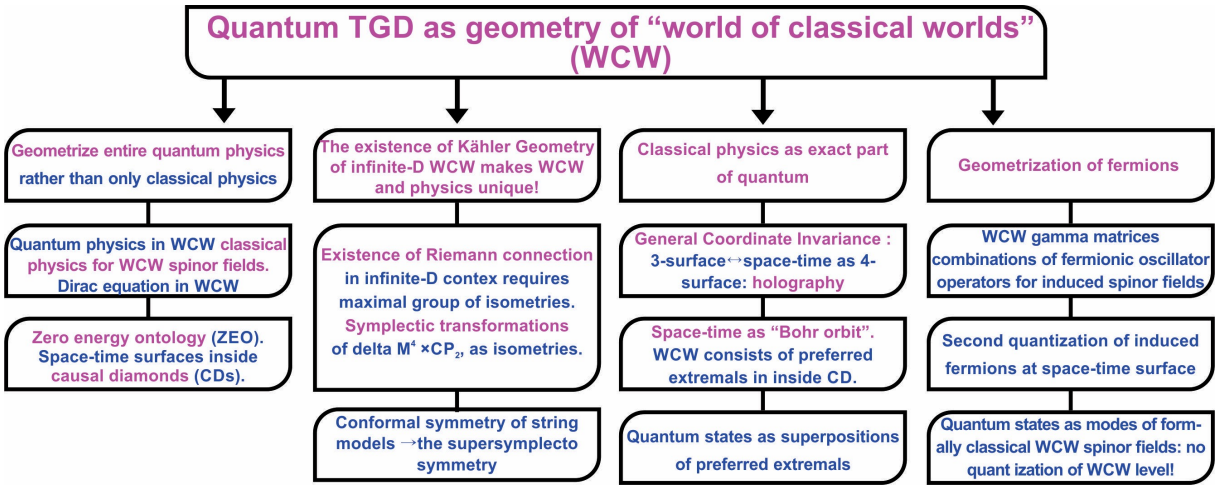


Figure 3: Geometrization of quantum physics in terms of WCW

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

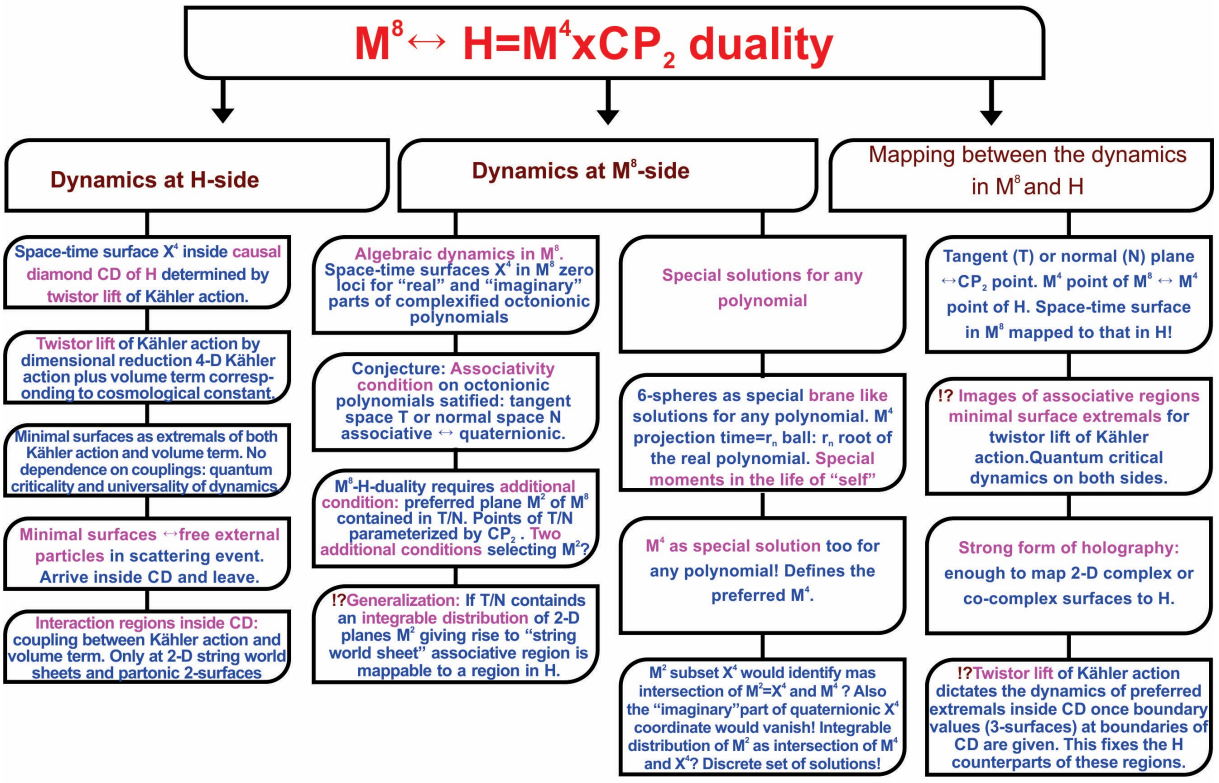


Figure 4: $M^8 - H$ duality

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

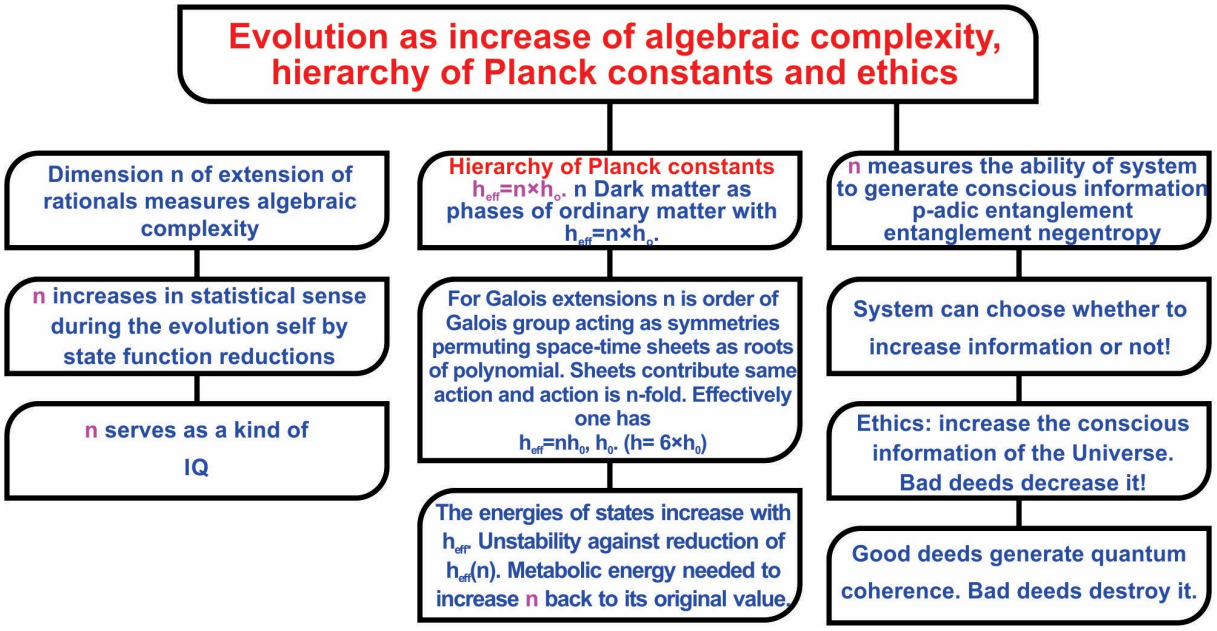


Figure 5: Number theoretic view of evolution

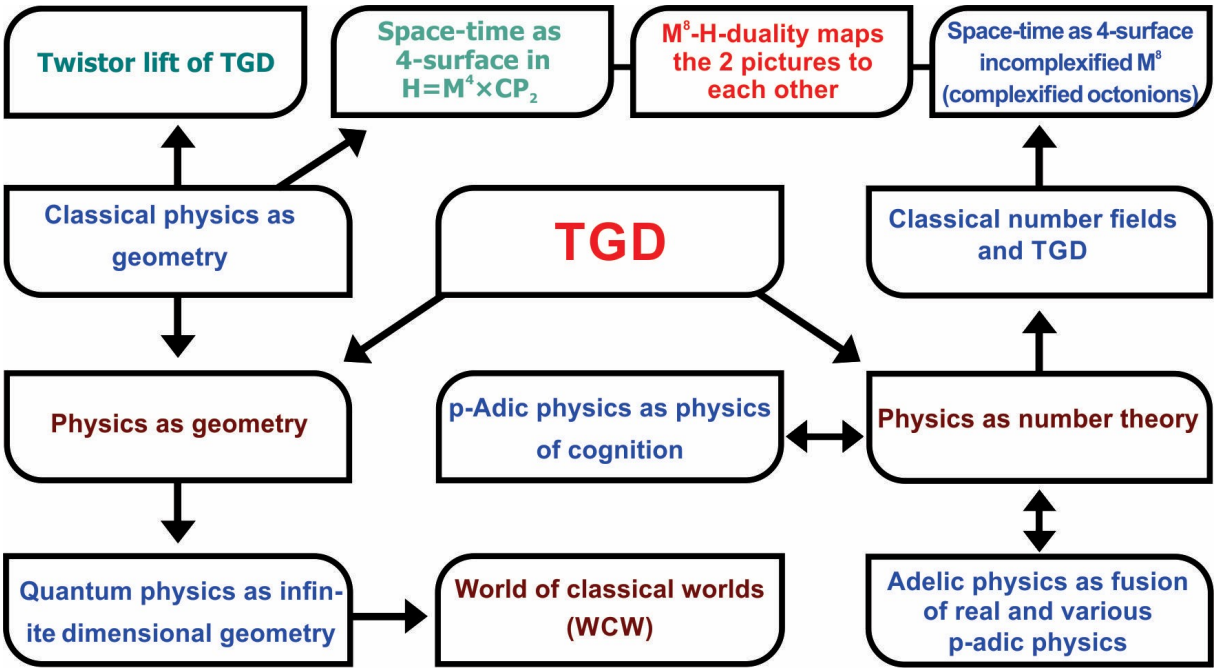


Figure 6: TGD is based on two complementary visions: physics as geometry and physics as number theory.

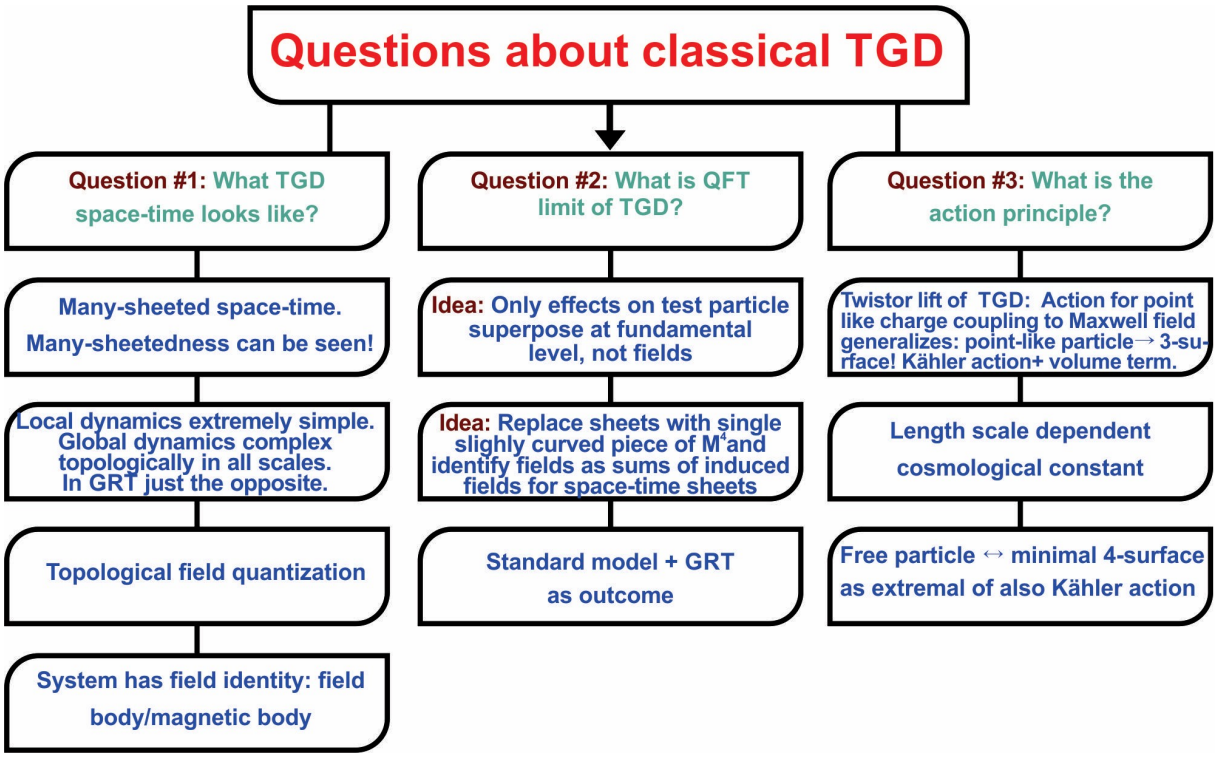


Figure 7: Questions about classical TGD.

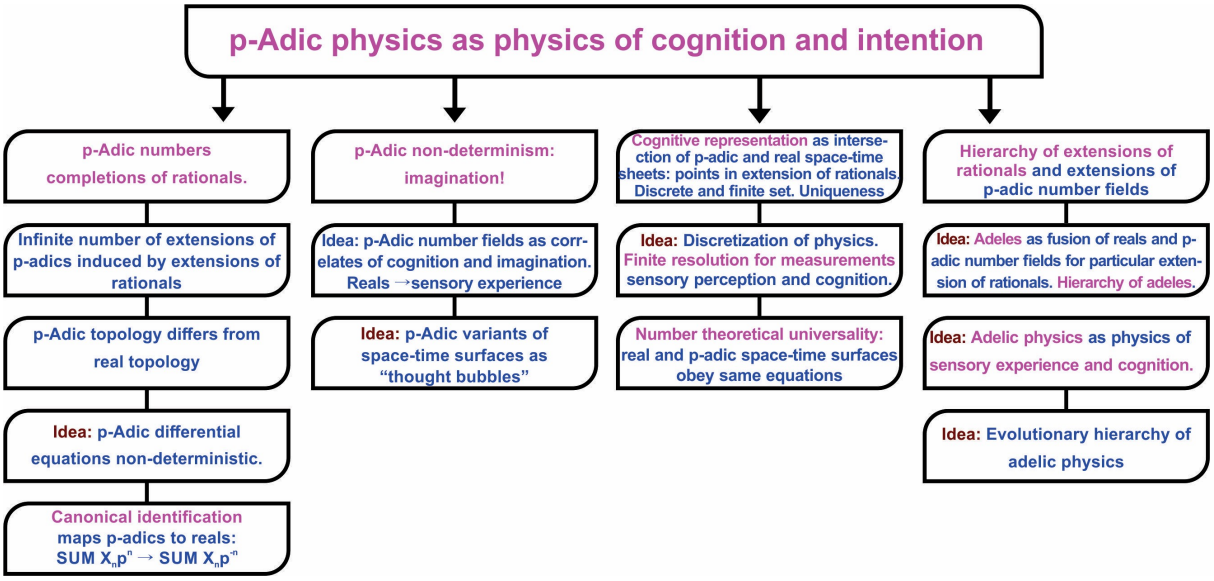


Figure 8: p-Adic physics as physics of cognition and imagination.

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.

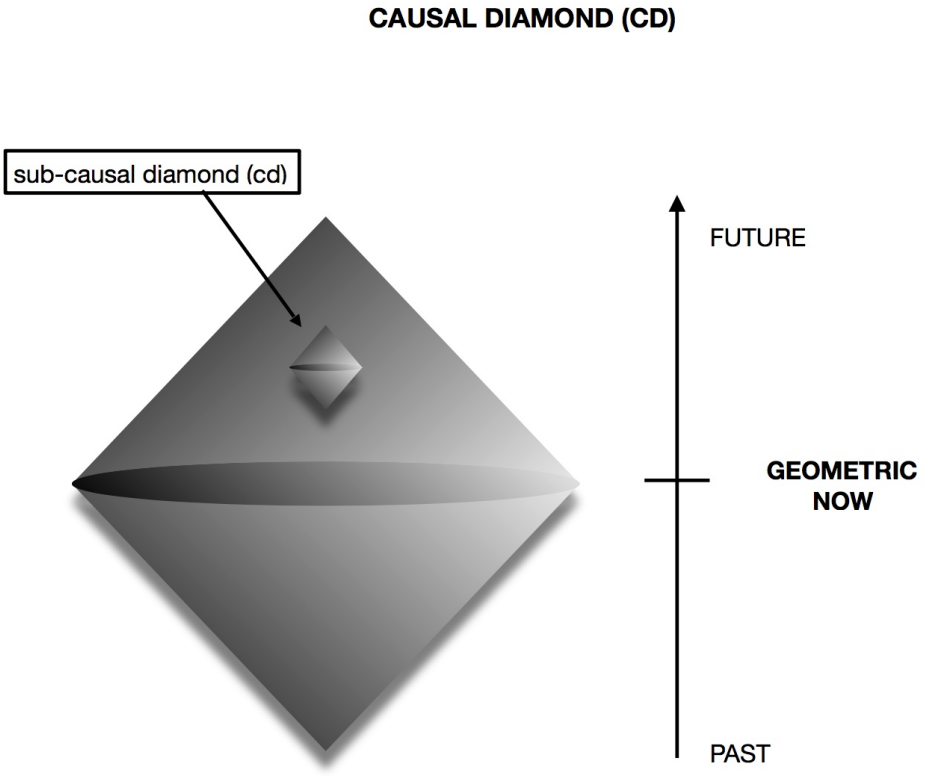


Figure 9: Causal diamond

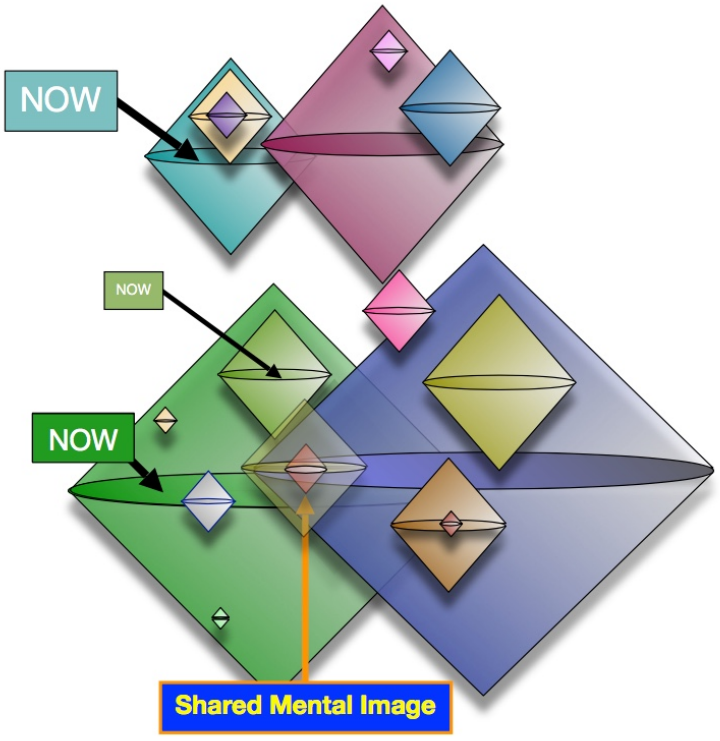


Figure 10: CDs define a fractal "conscious atlas"

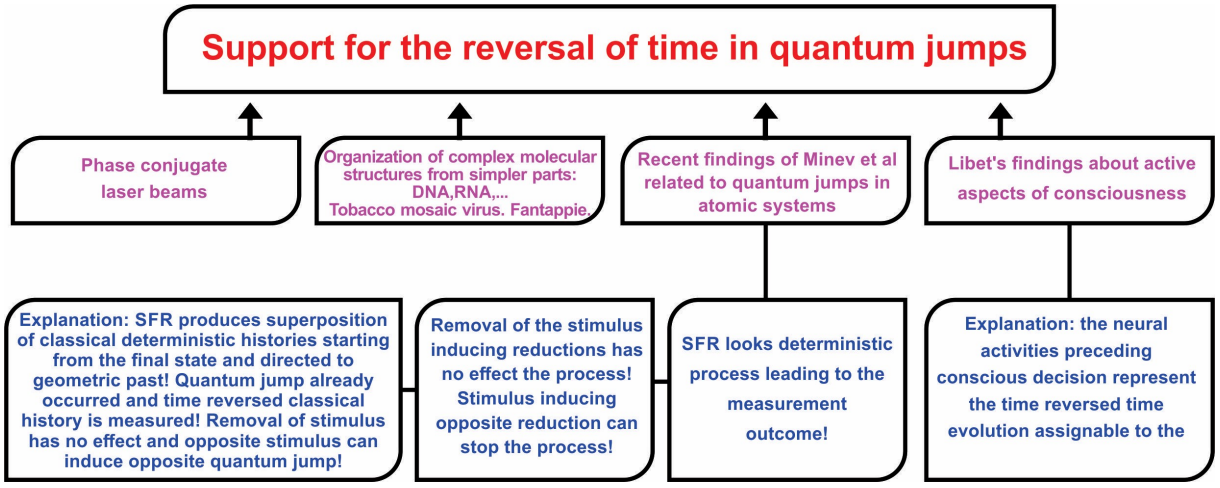


Figure 11: Time reversal occurs in BSFR

Figures

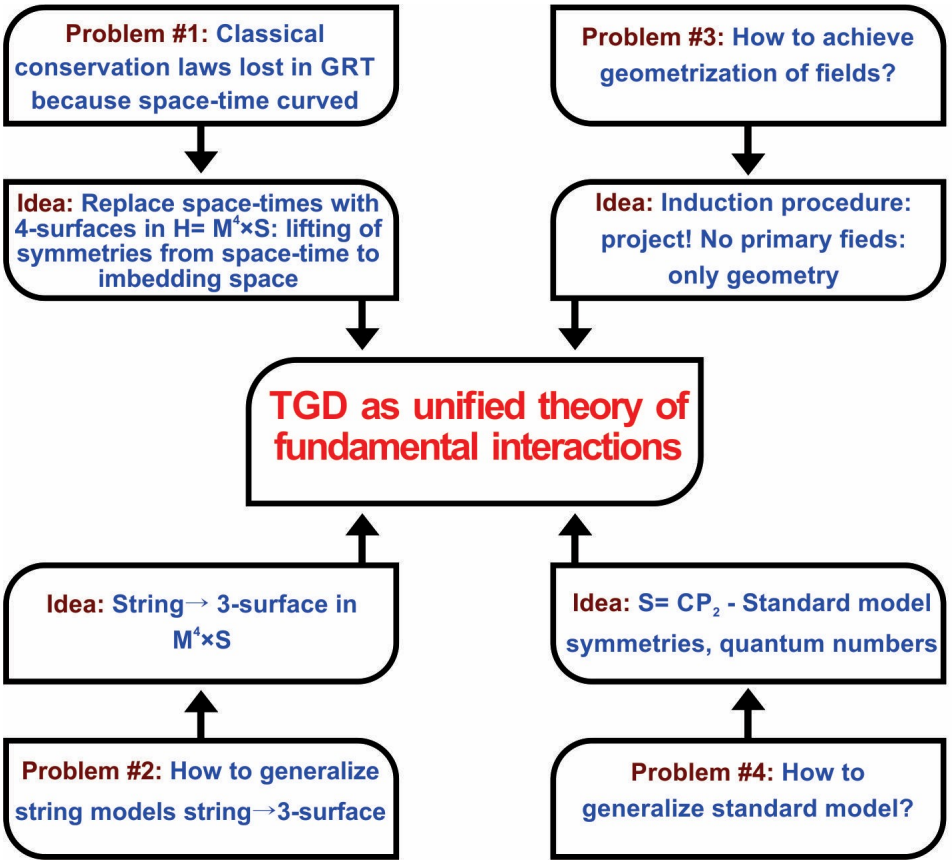
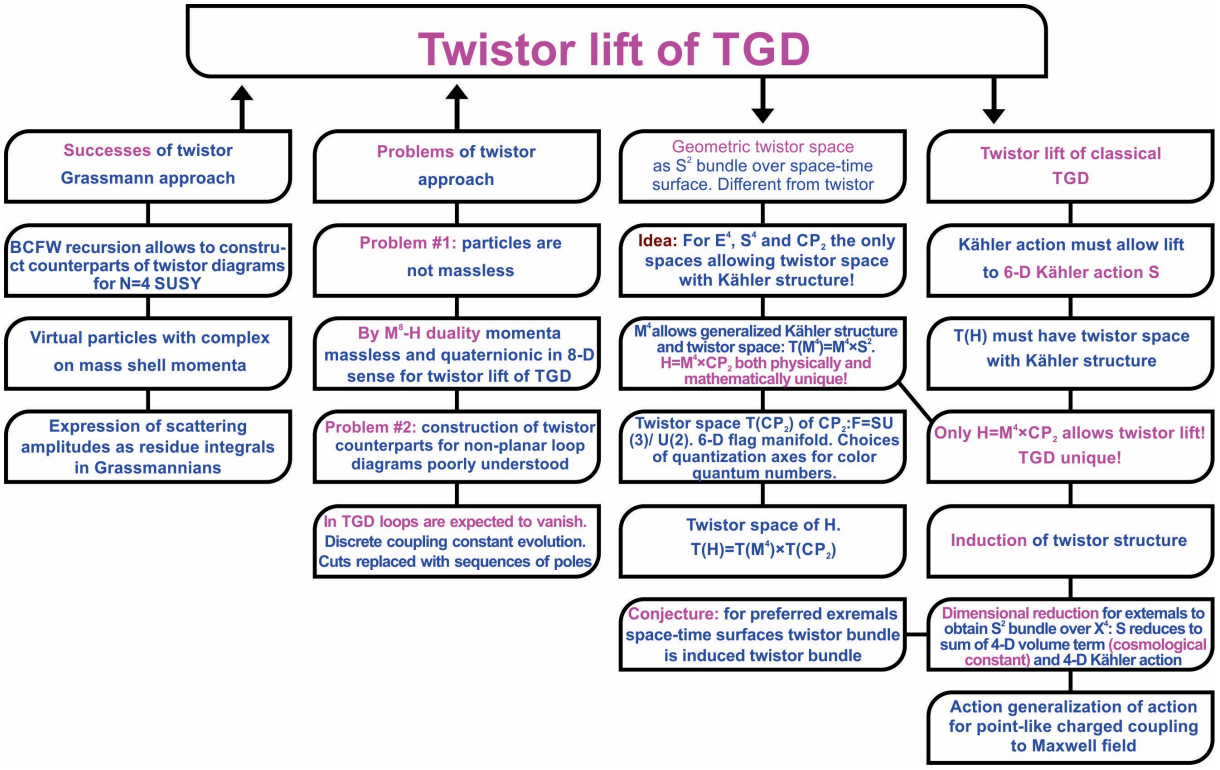


Figure 12: The problems leading to TGD as their solution.

What I have said above is strongly biased view about the recent situation in quantum TGD. This vision is single man's view and doomed to contain unrealistic elements as I know from experience. My dream is that young critical readers could take this vision seriously enough to try to demonstrate that some of its basic premises are wrong or to develop an alternative based on these or better premises. I must be however honest and tell that 45 years of TGD is a really vast bundle of thoughts and quite a challenge for anyone who is not able to cheat himself by taking the attitude of a blind believer or a light-hearted debunker trusting on the power of easy rhetoric tricks.

Karkkila, April 22, 2024, Finland

Matti Pitkänen



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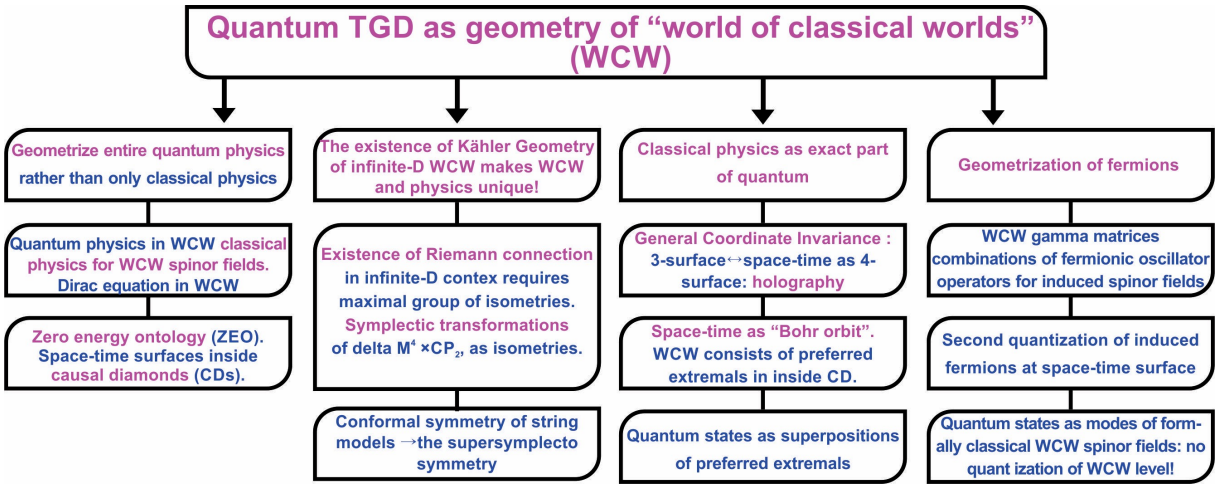


Figure 14: Geometrization of quantum physics in terms of WCW

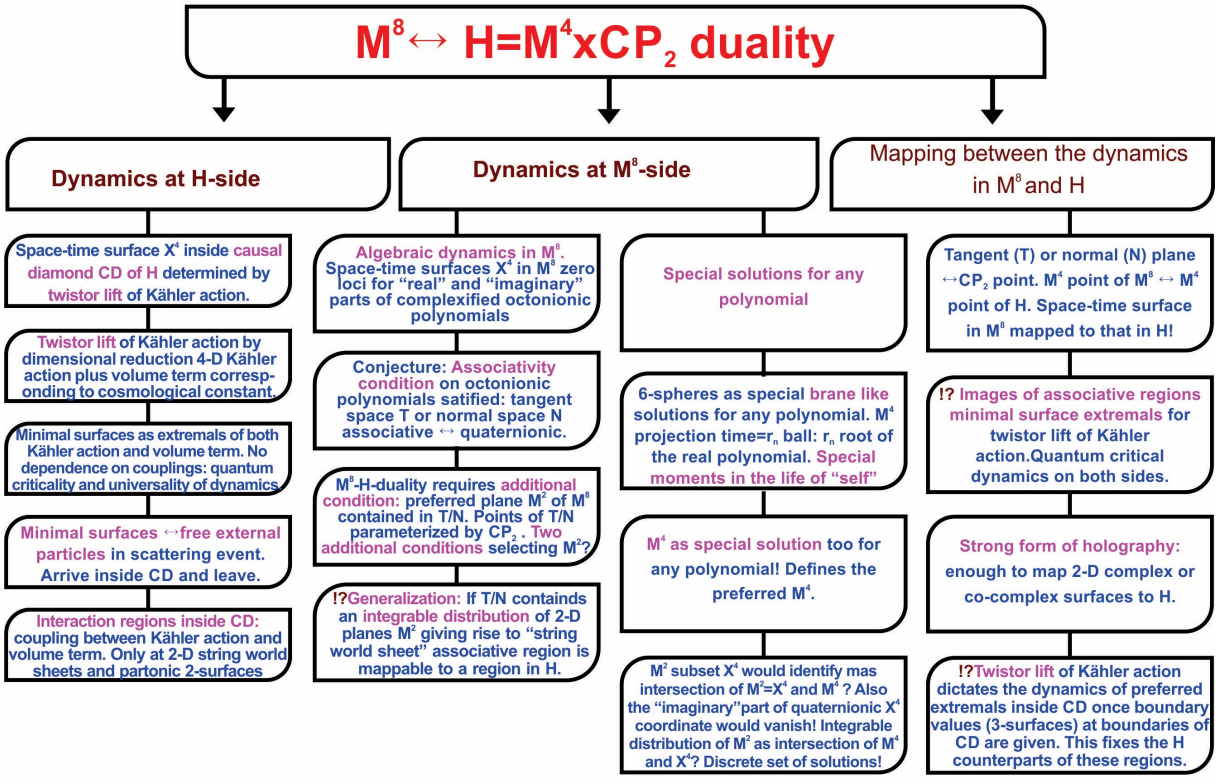


Figure 15: $M^8 - H$ duality

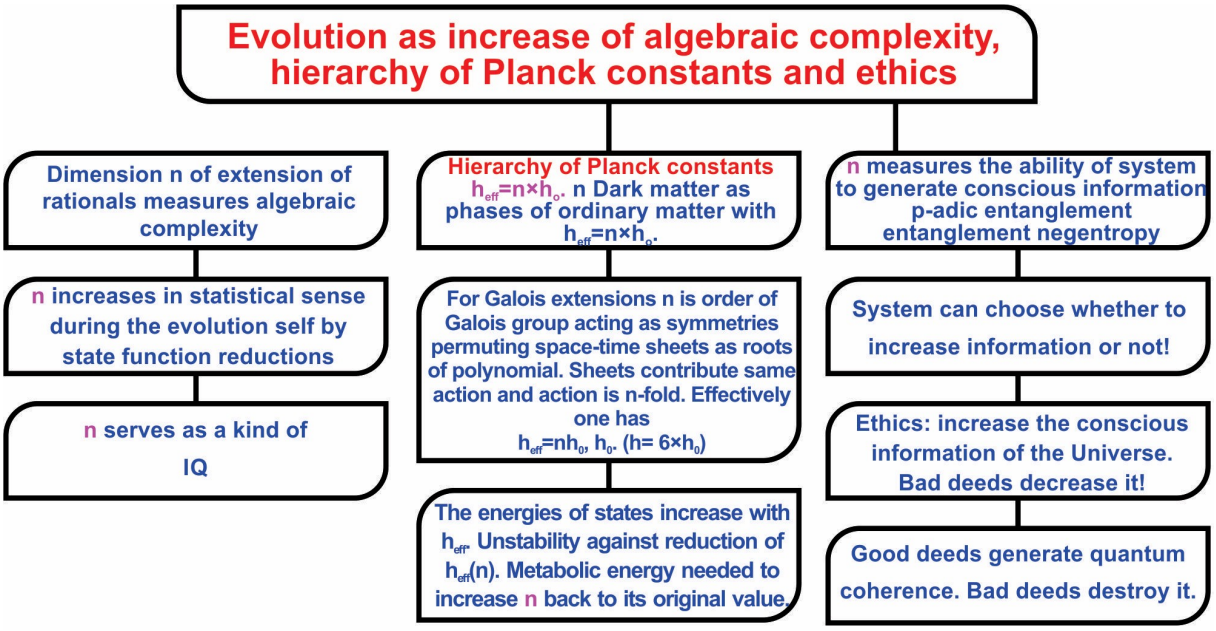


Figure 16: Number theoretic view of evolution

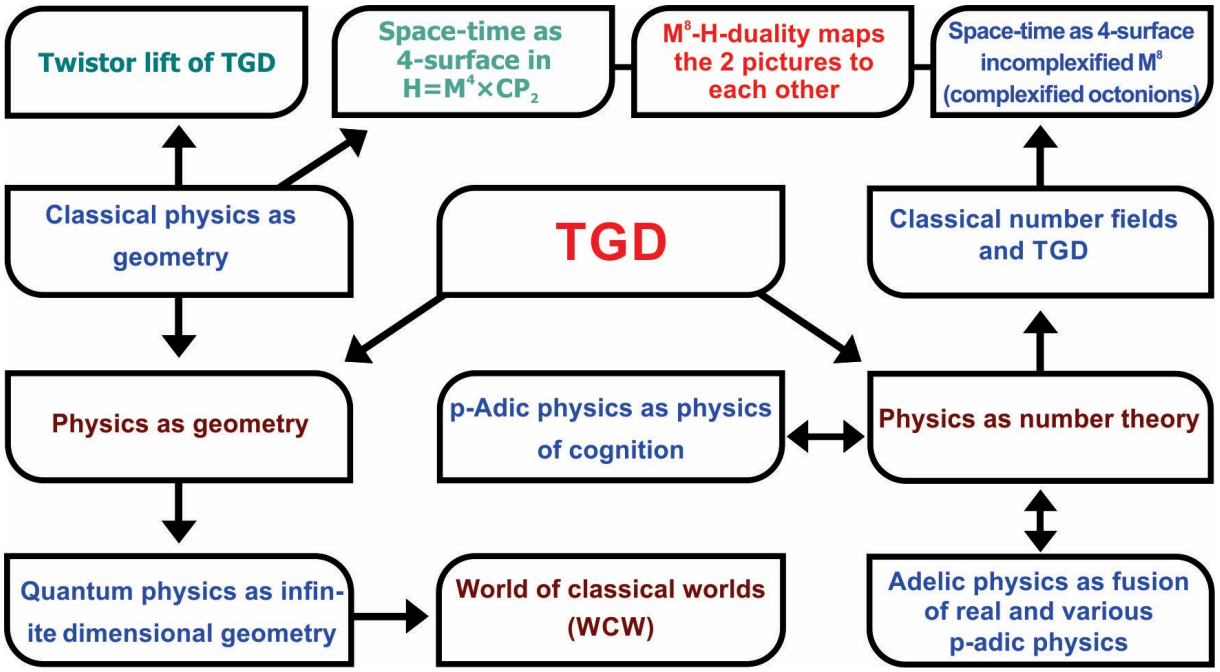
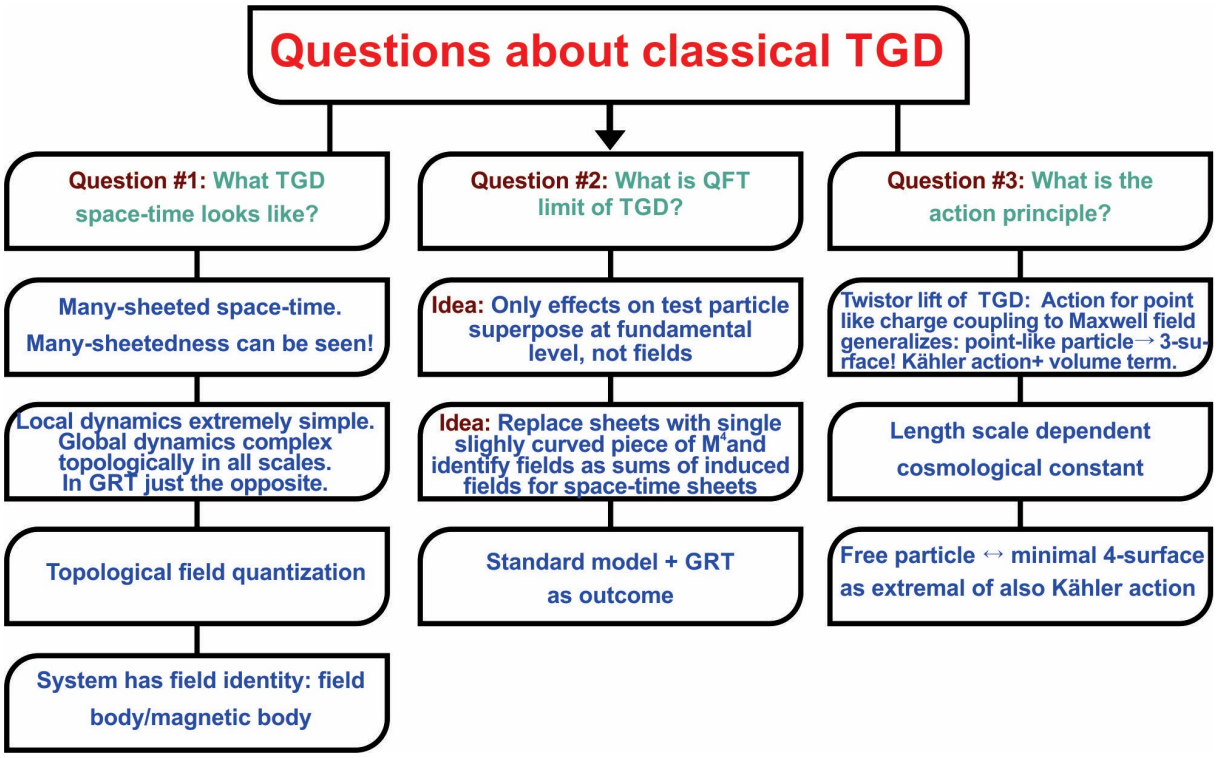


Figure 17: TGD is based on two complementary visions: physics as geometry and physics as number theory.



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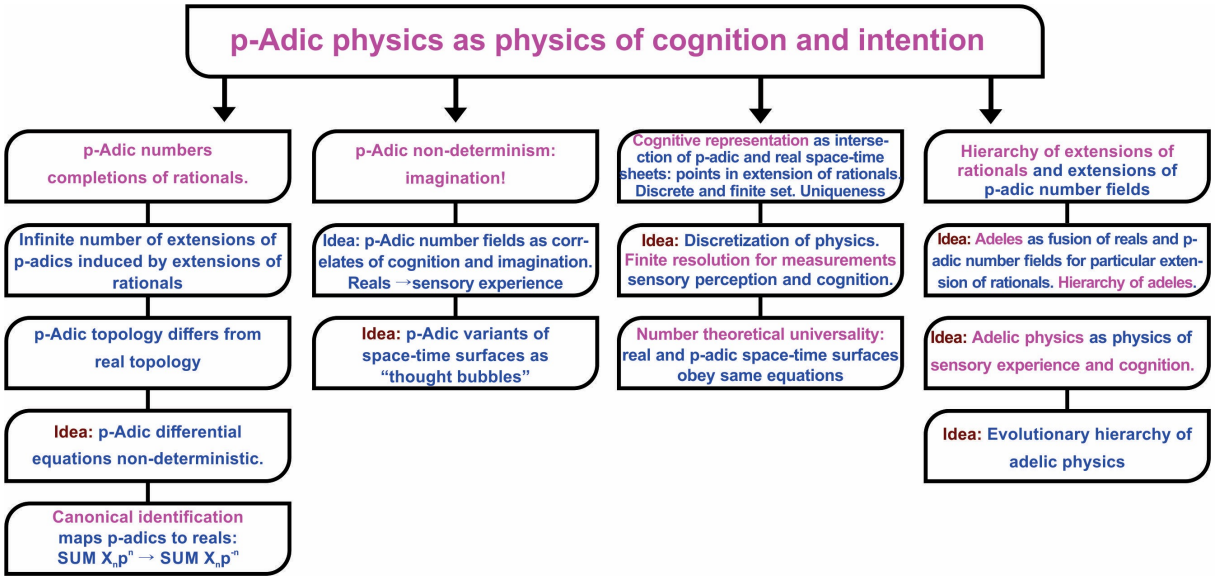


Figure 19: p-Adic physics as physics of cognition and imagination.

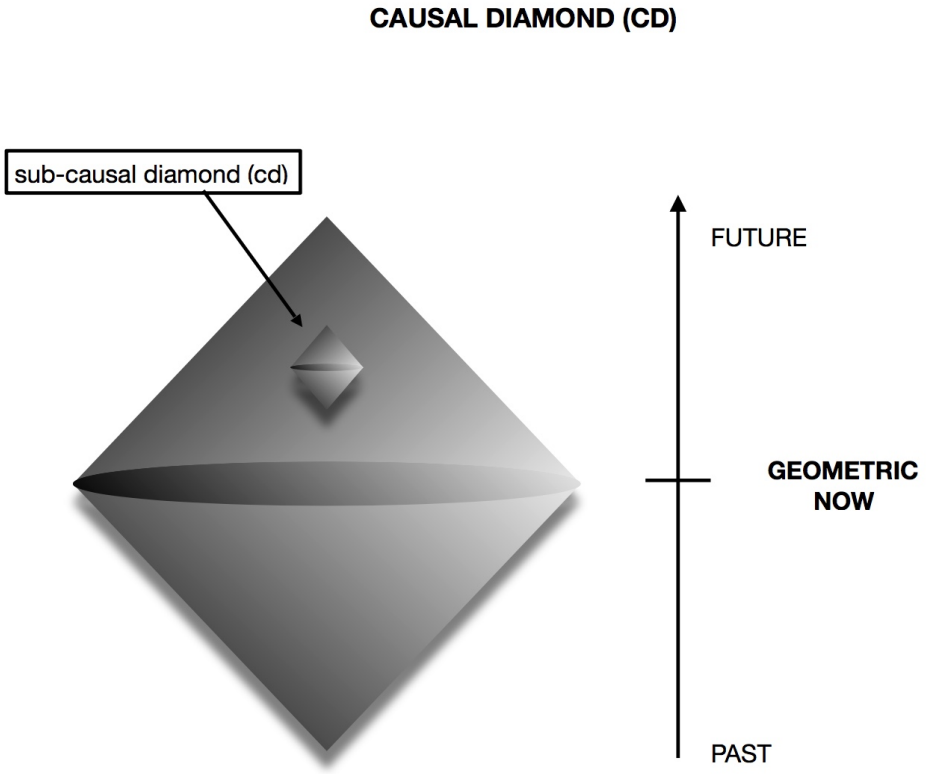
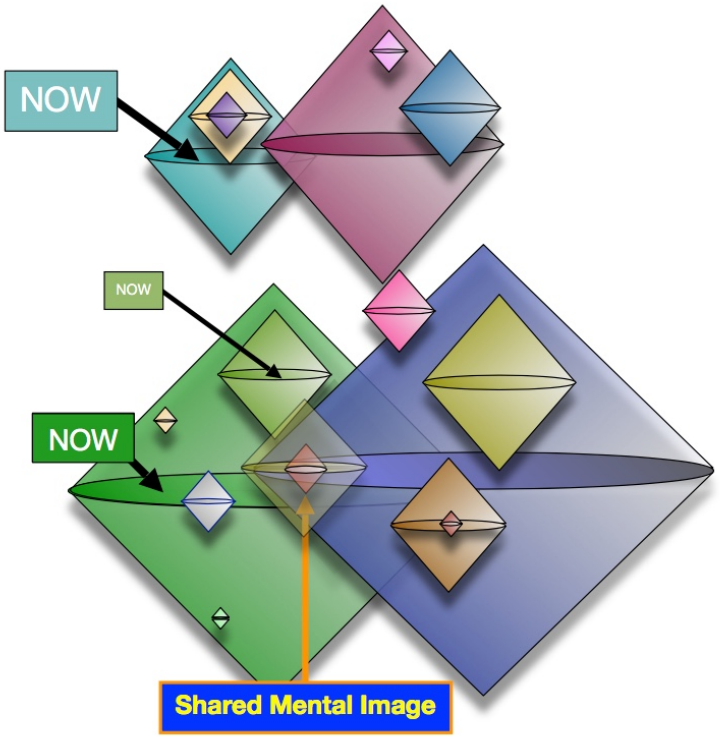


Figure 20: Causal diamond



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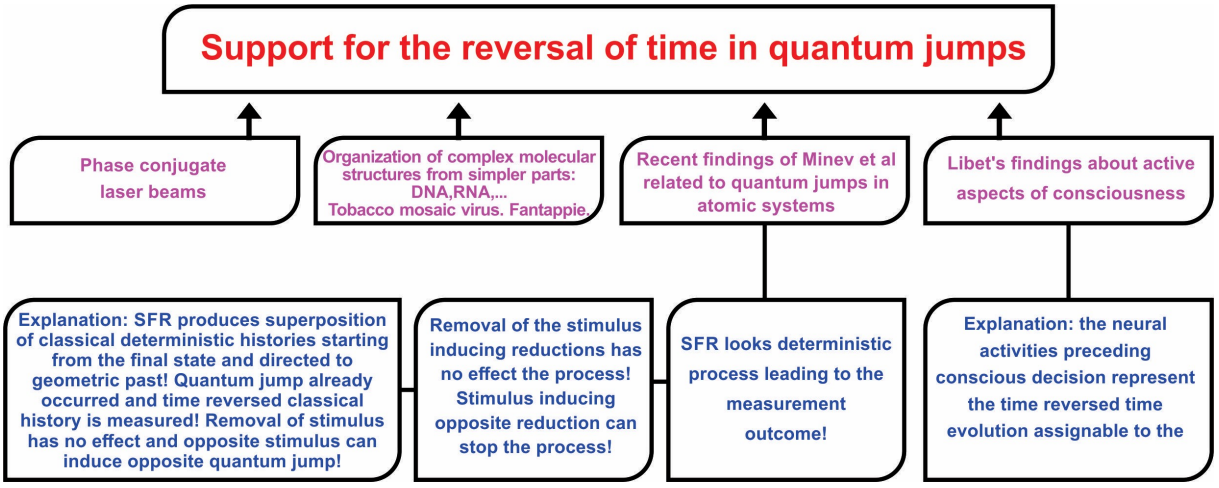

Figure 22: Time reversal occurs in BSFR

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 [K2].

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 [A3] [B22, B18, B19]), 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 [B15]) 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 [A14, A20, A9, A18].

The identification of the space-time as a sub-manifold [A15, A24] of $M^4 \times CP_2$ leads to an exact Poincare invariance and solves the conceptual difficulties related to the definition of the energy-momentum in General Relativity.

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

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

TGD as a Generalization of the Hadronic String Model

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

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

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

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

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

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

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

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

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

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

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

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

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

1.1.3 Basic Objections

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

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

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

Topological Field Quantization

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

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

1.1.4 Quantum TGD as Spinor Geometry of World of Classical Worlds

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

World of Classical Worlds

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

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

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

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

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

Identification of Kähler function

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

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

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

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

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

WCW spinor fields

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

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

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

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

The role of modified Dirac action

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

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

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

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

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

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

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

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

1.1.5 Construction of scattering amplitudes

Reduction of particle reactions to space-time topology

Particle reactions are identified as topology changes [A22, A27, A31]. For instance, the decay of a 3-surface to two 3-surfaces corresponds to the decay $A \to B + C$. 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 [K64]. This conforms with the idea about unitary time evolution as exponent of Hamiltonian discretized to integer power of S and represented as scaling with respect to the logarithm of the proper time distance between the tips of CD.

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

1.1.6 TGD as a generalized number theory

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

The Threads in the Development of Quantum TGD

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

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

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

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

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

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

Number theoretic vision very briefly

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

emerge as so called ramified primes of algebraic extension of rationals in question and characterizing string world sheets and partonic 2-surfaces. Preferred p-adic primes would be ramified primes for extensions for which the number of p-adic continuations of two-surfaces to space-time surfaces (imaginations) allowing also real continuation (realization of imagination) would be especially large. These ramifications would be winners in the fight for number theoretical survival. Also a generalization of p-adic length scale hypothesis emerges from NMP [K60].

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

Infinite primes

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

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

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

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

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

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

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

Holography in H

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

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

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

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

Number theoretic holography in M_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 $Re(E)^2$.

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

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 $SU(3) \to CP_2$ 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_c^8 and $M^4 \times CP_2$?

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

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

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

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

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

1.1.8 Hierarchy of Planck Constants and Dark Matter Hierarchy

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

Dark Matter as Large $\hbar$ Phases

D. Da Rocha and Laurent Nottale [E1] have proposed that Schrödinger equation with Planck constant $\hbar$ replaced with what might be called gravitational Planck constant $\hbar_{gr} = \frac{GmM}{v_0}$ ($\hbar = c = 1$). v_0 is a velocity parameter having the value $v_0 = 144.7 \pm .7$ km/s giving $v_0/c = 4.6 \times 10^{-4}$. This is rather near to the peak orbital velocity of stars in galactic halos. Also subharmonics and harmonics of v_0 seem to appear. The support for the hypothesis coming from empirical data is impressive.

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

Nottale's hypothesis would predict a gigantic value of h_{gr}. Equivalence Principle and the independence of gravitational Compton length on mass m implies however that one can restrict the values of mass m to masses of microscopic objects so that h_{gr} would be much smaller. Large h_{gr} could provide a solution of the black hole collapse (IR catastrophe) problem encountered at the classical level. The resolution of the problem inspired by TGD inspired theory of living matter is that it is the dark matter at larger space-time sheets which is quantum coherent in the required time scale [K89].

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 [K77, K78, K75]) 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 [K101]. 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 [L48].

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 [L37]. 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 TGD As A Generalization Of Physics To A Theory Consciousness

General Coordinate Invariance forces the identification of quantum jump as quantum jump between entire deterministic quantum histories rather than time=constant snapshots of single history. The new view about quantum jump forces a generalization of quantum measurement theory such that observer becomes part of the physical system. The basic idea is that quantum jump can be identified as momentum of consciousness. Thus a general theory of consciousness is unavoidable outcome. This theory is developed in detail in the books [K99, K18, K74, K16, K43, K54, K58, K90, K98].

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

1. What does one mean with quantum jump? Can one overcome the basic problem of the standard quantum measurement theory, that which forcing Bohr to give up totally the idea about objective reality?

2. How do the experienced time and geometric time relate in this framework? How the arrow of subjective time translates to that of geometric time?

3. How to define conscious information? Is it conserved or even increased during time evolution as biological evolution suggests? How does this increase relate to second law implied basically by the randomness of state function reduction?

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

1.2.1 Quantum Jump As A Moment Of Consciousness

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

$$\Psi_i \to U\Psi_i \to \Psi_f \quad ,$$

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

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

The M-matrices associated with CDs are obtained by a discrete scaling from the minimal CD and characterized by integer n are naturally proportional to S^n, where S is the S-matrix associated with the minimal CD. This conforms with the idea about unitary time evolution as exponent of Hamiltonian discretized to integer power of S.

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

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

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

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

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

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

1. The basic objection is that the arrow of geometric time alternates at embedding space level but we know that arrow of time looks the same in the part of the Universe we live. Possible exceptions however exist, for instance phase conjugate laser beams seem to obey opposite arrow of time. Also biological phenomena might involve non-standard arrow of time at some levels. This led Fantappie [J30] to introduce the notion of syntropy. This suggests that the arrow of time depends on the size scale of CD and of space-time sheet.

2. It took some time to realize that the solution of the problem is trivial in ZEO. In the ordinary quantum measurement theory one must assume that state function reduction can occur repeatedly: the assumption is that nothing happens to the state during repeated reductions. The outcome is Zeno effect: the watched pot does not boil.

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

3. The sequence of state function reductions on a fixed boundary of CD leads to the increase of the average temporal distance between the tips of CDs and this gives rise to the experience about flow of time as shifting of contents of perception towards future if the change is what contributes to conscious experience and gives rise to a fixed arrow of time.

4. Contrary to original working hypothesis, state function reduction in the usual sense does not solely determine the ordinary conscious experience. It can however contribute to conscious experience and the act of free will is a good candidate in this respect. TGD view about realization of intentional action assumes that intentional actions involve negative energy signals propagating backwards in geometric time. This would mean that at some level of CD hierarchy the arrow of geometric time indeed changes and the reduction start to occur at opposite boundary of CD at some level of length scale hierarchy.

1.2.2 Negentropy Maximization Principle (NMP)

Information is the basic aspect of consciousness and this motivates the introduction of Negentropy Maximization Principle (NMP) [K60] as the fundamental variational principle of consciousness theory. The amount of negentropy of zero energy state should increase in each quantum jump. The ordinary entanglement entropy is also non-negative so that negentropy could be at best zero. Since p-adic physics is assumed to be a correlate of cognition, it is natural to generalizes Shannon entropy to its number theoretic variant by replacing the probabilities appearing as arguments of logarithms of probabilities with their p-adic norms. This gives negentropy which can be positive so that NMP can generates entanglement.

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

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

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

1.2.3 The Notion Of Self

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

1. The original view was that self corresponds to a subsystem able to remain un-entangled under the sequential informational "time evolutions" U. It is however unclear how it could be possible to avoid generation of entanglement.

2. In ZEO the situation changes. Self corresponds to a sequence of quantum jumps for which the parts of zero energy states at either boundary of CD remaim unchanged. Therefore one can say that self defined in terms of parts of states assignable to this boundary remains unaffected as sub-system and does not generate entanglement. At the other boundary changes occur and give rise to the experience of time flow and arrow of time since the average temporal distance between the tips of CD tends to increase.

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

3. It looks natural to assume that the experiences of the self after the last "wake-up" sum up to single average experience. This means that subjective memory is identifiable as conscious, immediate short term memory. Selves form an infinite hierarchy with the entire Universe at the top. Self can be also interpreted as mental images: our mental images are selves having mental images and also we represent mental images of a higher level self. A natural hypothesis is that self S experiences the experiences of its sub-selves as kind of abstracted experience: the experiences of sub-selves S_i are not experienced as such but represent kind of averages $\langle S_{ij} \rangle$ of sub-sub-selves S_{ij}. Entanglement between selves, most naturally realized by the formation of flux tube bonds between cognitive or material space-time sheets, provides a possible a mechanism for the fusion of selves to larger selves (for instance, the fusion of the mental images representing separate right and left visual fields to single visual field) and forms wholes from parts at the level of mental images.

4. Self corresponds in neuro science to self model defining a model for organism and for the external world. Information or negentropy seems to be necessary for understanding self. Negentropically entangled states - Akashic records - are excellent candidates for selves and would thus correspond to dark matter in TGD sense since the number of states in superposition corresponds to the integer n defining h_{eff}. It is enough that self is potentially conscious: this could mean that it conscious experience about self is generated only in interaction free measurement. Repeated state function reductions to given boundary of CD is second possibility. This would assign irreversibility and definite arrow of time and experience of time flow with self.

5. CDs would serve as embedding space correlates of selves and quantum jumps would be followed by cascades of state function reductions beginning from given CD and proceeding downwards to the smaller scales (smaller CDs). At space-time level space-time sheets in given p-adic length scale would be the natural correlates of selves. One ends also ends up with concrete ideas about how the localization of the contents of sensory experience and cognition to the "upper" (changing) boundary of CD could take place. One cannot exclude the possibility that state function reduction cascades could also take place in parallel branches of the quantum state.

1.2.4 Relationship To Quantum Measurement Theory

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

1. The standard quantum measurement theory a la von Neumann involves the interaction of brain with the measurement apparatus. If this interaction corresponds to entanglement between microscopic degrees of freedom m with the macroscopic effectively classical degrees of freedom M characterizing the reading of the measurement apparatus coded to brain state, then the reduction of this entanglement in quantum jump reproduces standard quantum measurement theory provide the unitary time evolution operator U acts as flow in zero mode degrees of freedom and correlates completely some orthonormal basis of WCW spinor fields in non-zero modes with the values of the zero modes. The flow property guarantees that the localization is consistent with unitarity: it also means 1-1 mapping of quantum state basis to classical variables (say, spin direction of the electron to its orbit in the external magnetic field).

2. The assumption that localization occurs in zero modes in each quantum jump implies that the world of conscious experience looks classical. It is also consistent with the state function reduction of the standard quantum measurement theory as the following arguments demonstrate (it took incredibly long time to realize this almost obvious fact!).

3. Since zero modes represent classical information about the geometry of space-time surface (shape, size, classical Kähler field, ...), they have interpretation as effectively classical degrees of freedom and are the TGD counterpart of the degrees of freedom M representing the reading of the measurement apparatus. The entanglement between quantum fluctuating non-zero modes and zero modes is the TGD counterpart for the $m - M$ entanglement. Therefore the localization in zero modes is equivalent with a quantum jump leading to a final state where the measurement apparatus gives a definite reading.

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

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

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

1.2.5 Selves Self-Organize

The fourth basic element is quantum theory of self-organization based on the identification of quantum jump as the basic step of self-organization [K85]. Quantum entanglement gives rise to the generation of long range order and the emergence of longer p-adic length scales corresponds to the emergence of larger and larger coherent dynamical units and generation of a slaving hierarchy. Energy (and quantum entanglement) feed implying entropy feed is a necessary prerequisite for quantum self-organization. Zero modes represent fundamental order parameters and localization in zero modes implies that the sequence of quantum jumps can be regarded as hopping in the zero modes so that Haken's classical theory of self organization applies almost as such. Spin glass analogy is a further important element: self-organization of self leads to some characteristic pattern selected by dissipation as some valley of the "energy" landscape.

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

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

1.2.6 Classical Non-Determinism Of Kähler Action

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

1. The huge vacuum degeneracy of the Kähler action suggests strongly that the preferred is not always unique. For instance, a sequence of bifurcations can occur so that a given space-time branch can be fixed only by selecting a finite number of 3-surfaces with time like(!) separations on the orbit of 3-surface. Quantum classical correspondence suggest an alternative formulation. Space-time surface decomposes into maximal deterministic regions and their temporal sequences have interpretation a space-time correlate for a sequence of quantum states defined by the initial (or final) states of quantum jumps. This is consistent with the fact that the variational principle selects preferred extremals of Kähler action as generalized Bohr orbits.

2. In the case that non-determinism is located to a finite time interval and is microscopic, this sequence of 3-surfaces has interpretation as a simulation of a classical history, a geometric correlate for contents of consciousness. When non-determinism has long lasting and macroscopic effect one can identify it as volitional non-determinism associated with our choices. Association sequences relate closely with the cognitive space-time sheets defined as space-time sheets having finite time duration.

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

1.2.7 P-Adic Physics As Physics Of Cognition

A further basic element adds a physical theory of cognition to this vision. TGD space-time decomposes into regions obeying real and p-adic topologies labelled by primes $p = 2, 3, 5, ...$ p-Adic regions obey the same field equations as the real regions but are characterized by p-adic non-determinism since the functions having vanishing p-adic derivative are pseudo constants which are piecewise constant functions. Pseudo constants depend on a finite number of positive pinary digits of arguments just like numerical predictions of any theory always involve decimal cutoff. This means that p-adic space-time regions are obtained by gluing together regions for which integration

constants are genuine constants. The natural interpretation of the p-adic regions is as cognitive representations of real physics. The freedom of imagination is due to the p-adic non-determinism. p-Adic regions perform mimicry and make possible for the Universe to form cognitive representations about itself. p-Adic physics space-time sheets serve also as correlates for intentional action.

A more precise formulation of this vision requires a generalization of the number concept obtained by fusing reals and p-adic number fields along common rationals (in the case of algebraic extensions among common algebraic numbers). This picture is discussed in [K95] . The application this notion at the level of the embedding space implies that embedding space has a book like structure with various variants of the embedding space glued together along common rationals (algebraics, see **Fig.** `http://tgdtheory.fi/appfigures/book.jpg` or **Fig. ??** in the appendix of this book). The implication is that genuinely p-adic numbers (non-rationals) are strictly infinite as real numbers so that most points of p-adic space-time sheets are at real infinity, outside the cosmos, and that the projection to the real embedding space is discrete set of rationals (algebraics). Hence cognition and intentionality are almost completely outside the real cosmos and touch it at a discrete set of points only.

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

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

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

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

1. Macroscopic quantum coherence can be understood since a particle with a given mass can in principle appear as arbitrarily large scaled up copies (Compton length scales as $\hbar$). The phase transition to this kind of phase implies that space-time sheets of particles overlap and this makes possible macroscopic quantum coherence.

2. The space-time sheets with large Planck constant can be in thermal equilibrium with ordinary ones without the loss of quantum coherence. For instance, the cyclotron energy scale associated with EEG turns out to be above thermal energy at room temperature for the level of dark matter hierarchy corresponding to magnetic flux quanta of the Earth's magnetic field with the size scale of Earth and a successful quantitative model for EEG results [K35].

Dark matter hierarchy leads to detailed quantitative view about quantum biology with several testable predictions [K35]. The general prediction is that Universe is a kind of inverted Mandelbrot fractal for which each bird's eye of view reveals new structures in long length and time scales representing scaled down copies of standard physics and their dark variants. These structures would correspond to higher levels in self hierarchy. This prediction is consistent with the belief that 75 per cent of matter in the universe is dark.

1. Living matter and dark matter

Living matter as ordinary matter quantum controlled by the dark matter hierarchy has turned out to be a particularly successful idea. The hypothesis has led to models for EEG predicting correctly the band structure and even individual resonance bands and also generalizing the notion of EEG [K35]. Also a generalization of the notion of genetic code emerges resolving the paradoxes related to the standard dogma [K56, K35]. A particularly fascinating implication is the possibility

to identify great leaps in evolution as phase transitions in which new higher level of dark matter emerges [K35].

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

2. Dark matter hierarchy and the notion of self

The vision about dark matter hierarchy leads to a more refined view about self hierarchy and hierarchy of moments of consciousness [K34, K35]. The larger the value of Planck constant, the longer the life-time of self measured as the increase of the average distance between tips of CDs appearing in the quantum superposition during the period of repeated reductions not affecting the part of the zero energy state at the other boundary of CD- Quantum jumps form also a hierarchy with respect to p-adic and dark hierarchies and the geometric durations of quantum jumps scale like $\hbar$.

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

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

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

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

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

Higher levels of dark matter hierarchy provide a neat quantitative view about self hierarchy and its evolution. Various levels of dark matter hierarchy would naturally correspond to higher levels in the hierarchy of consciousness and the typical duration of life cycle would give an idea about the level in question. The level would determine also the time span of long term memories as discussed in [K35]. The emergence of these levels must have meant evolutionary leap since long term memory is also accompanied by ability to anticipate future in the same time scale. This picture would suggest that the basic difference between us and our cousins is not at the level of genome as it is usually understood but at the level of the hierarchy of magnetic bodies [K56, K35]. In fact, higher levels of dark matter hierarchy motivate the introduction of the notions of super-genome and hyper-genome. The genomes of entire organ can join to form super-genome expressing genes coherently. Hyper-genomes would result from the fusion of genomes of different organisms and collective levels of consciousness would express themselves via hyper-genome and make possible

social rules and moral.

1.3 Quantum Biology And Quantum Neuroscience In TGD Universe

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

1.3.1 Basic Physical Ideas

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

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

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

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

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

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

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

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

5. p-Adic physics can be identified as physics of cognition and intentionality. The hierarchy of p-adic length scales predicts a hierarchy of universal metabolic quanta as increments of zero point kinetic energies. Negentropic entanglement (see **Fig.** `http://tgdtheory.fi/appfigures/cat.jpg` or **Fig. ??** in the appendix of this book) possible for number theoretic entanglement entropy makes sense for rational (and even algebraic) entanglement and leads to the identification of life as something residing in the intersection of real and p-adic worlds. NMP respects negentropic entanglement and the attractive idea is that the experience of understanding and positively colored emotions relate to negentropic entanglement.

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

1.3.2 Brain In TGD Universe

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

1. An attractive idea is that the negentropic entanglement can be assigned with magnetic flux tubes somehow and that ATP serves as a correlate for negentropic entanglement. This leads to a rather detailed ideas about the role of phosphate bond and provides interpretation for the fact that the number of valence bonds tend to be maximized in living matter. In a loose sense one could even call ATP a consciousness molecule. The latest view encourages to consider the possibility that negentropic entanglement with what might be called Mother Gaia is what is transferred in metabolism.

2. The view about the function of brain differs from the standard view. The simplest option is that brain is a builder of symbolic representations building percepts and giving them names rather than the seat of primary qualia relevant to our conscious experience. Sensory organs

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

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

1.3.3 Anomalies

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

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

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

3. Metabolic energy is necessary for conscious information processing in living matter. This suggests that metabolism should be basically transfer of negentropic entanglement from nutrients to the organism. ATP could be seen as a molecule of consciousness in this picture and high energy phosphate bond would make possible the transfer of negentropy.

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

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

1. The oldest layers in the stratigraphy are the vision about DNA inspired by the notion of many-sheeted space-time and the model of genetic code inspired by the notion of Combinatorial Hierarchy predicting also the existence of what I have called memetic code. Additional number theoretical models of genetic code based on p-adic thermodynamics for small p-adic primes and maximization of entropy or negentropy emerged much later. One must however admit that although these models reproduce the genetic code they fail to predict it. Models also fail also to make interesting predictions.

2. The almost exact symmetries of the code table with respect to the first letter lead to the proposal that the genetic code could has evolved from a simpler code involving only two letters and this leads to concrete suggestion about how the genetic code might have evolved

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

3. The work with a model of topological quantum computation inspired by the vision about dark matter hierarchy and the idea that genome and cell membrane act as topological quantum computer generated several new chapters. The magnetic flux tubes as carriers of dark matter characterized by a large value of Planck constant would make living matter a macroscopic quantum system. DNA nucleotides and lipids of the cell membrane would be connected by magnetic flux tubes and the flow of the 2-D liquid formed by lipids induces braiding of flux tubes providing both temporal dynamics defining topological quantum computation and a storage of the program to memory by the braiding of flux tubes in the final state.

4. This model led to a cascade of ideas about quantum control in living matter. Quite generally, magnetic flux tubes would make living matter kind of Indra's net explaining the strange features of gel phase. For instance, the phase transitions changing Planck constant inducing a contraction or lengthening of the flux tubes would explain why bio-molecules are able to find each other extremely selectively in the dense soup of bio-molecules inside cell. The anomalies related to ionic currents find an explanation and a model of nerve pulse and EEG emerges along these lines.

5. The discoveries of Peter Gariaev about the interaction of ordinary and laser light with genome combined with the ideas about dark matter and water memory led to a concrete model for the interaction of photons with DNA. One prediction is that it is possible to "see" dark matter by allowing ordinary matter interaction with DNA and Peter Gariaev might have already done this. In this process ordinary photons would transform to dark ones, scatter from dark matter, transform back to ordinary photons and arrive at camera. A second discovery - certainly one of the greatest surprises of my professional life - was an end product of an attempt to understand the mechanism behind water memory for which rather strong support exists now. The idea was that dark nuclei which sizes zoomed up to atomic size scale could provide a representation of genes.

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

1.4.1 Organization of"Genes and Memes: Part I"

The topics of the first part of "Genes and Memes: Part I" are organized in 2 parts.

1. In the 1st part of the book I will discuss the new physics relevant to biology suggested by TGD and consider a general model for how TGD Universe could act as topological quantum computer. Two chapters are devoted to the model of DNA as topological quantum computer and the ideas inspired by it. The braiding of magnetic flux tubes making TQC possible is extremely general concept and therefore one can consider that many variants of the model. Moreover, the proposed models certainly contain unrealistic elements.

2. In the 2nd part of the book mostly physics inspired ideas about genome are considered. The idea that there exists a hierarchy of analogs of genetic code based on the notion of Combinatorial Hierarchy is discussed. The hierarchy would contain at least three levels including predecessor of genetic code, genetic code, and what I have coined as memetic code. The chapter devoted to the notion of many-sheeted DNA represents rather old contributions and the original model is not yet realistic. There are 3 chapters about TGD interpretation of findings of Peter Gariaev and his research group. The last chapter represents a model of protein folding and bio-catalysis.

1.5 Sources

The eight online books about TGD [K108, K102, K84, K67, K21, K65, K48, K91] and nine online books about TGD inspired theory of consciousness and quantum biology [K99, K18, K74, K16, K43, K54, K58, K90, K98] are warmly recommended for the reader willing to get overall view about what is involved.

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

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

1.6 The contents of the book

1.6.1 PART I: TOPOLOGICAL QUANTUM COMPUTATION IN TGD UNIVERSE

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.

Topological Quantum Computation in TGD Universe

Topological quantum computation (TQC) is one of the most promising approaches to quantum computation. The coding of logical qubits to the entanglement of topological quantum numbers promises to solve the de-coherence problem whereas the S-matrices of topological field theories (modular functors) providing unitary representations for braids would give a realization of quantum computer programs with gates represented as simple braiding operations. Because of their effective 2-dimensionality anyon systems are the best candidates for realizing the representations of braid groups.

TGD allows several new insights related to quantum computation. TGD predicts new information measures as number theoretical negative valued entanglement entropies defined for systems having extended rational entanglement and characterizes bound state entanglement as bound state entanglement. Hierarchy of Planck constants labelling phases of dark matter makes possible macroscopic quantum coherence. Negentropy Maximization Principle and p-adic length scale hierarchy of space-time sheets encourage to believe that Universe itself might do its best to resolve the de-coherence problem. The new view about quantum jump suggests strongly the notion of quantum parallel dissipation so that thermalization in shorter length scales would guarantee coherence in longer length scales. The possibility of negative energies and communications to geometric future in turn might even trivialize the problems caused by long computation times: computation could be iterated again and again by turning the computer on in the geometric past and TGD inspired theory of consciousness predicts that something like this occurs routinely in living matter.

Kähler action defines the basic variational principle of classical TGD and predicts extremely complex but non-chaotic magnetic flux tube structures, which can get knotted and linked. The

dimension of CP_2 projection for these structures is $D = 3$. These structures are the corner stone of TGD inspired theory of living matter and provide the braid structures needed by TQC.

Anyons are the key actors of TQC and TGD leads to detailed model of anyons as systems consisting of track of a periodically moving charged particle realized as a flux tube containing the particle inside it. This track would be a space-time correlate for the outcome of dissipative processes producing the asymptotic self-organization pattern. These tracks in general carry vacuum Kähler charge which is topologized when the CP_2 projection of space-time sheet is $D = 3$. This explains charge fractionization predicted to occur also for other charged particles. When a system approaches chaos periodic orbits become slightly aperiodic and the correlate is flux tube which rotates N times before closing. This gives rise to Z_N valued topological quantum number crucial for TQC using anyons ($N = 4$ holds true in this case). Non-Abelian anyons are needed by TQC, and the existence of long range classical electro-weak fields predicted by TGD is an essential prerequisite of non-Abelianity.

Negative energies and zero energy states are of crucial importance of TQC in TGD. The possibility of phase conjugation for fermions would resolve the puzzle of matter-antimatter asymmetry in an elegant manner. Anti-fermions would be present but have negative energies. Quite generally, it is possible to interpret scattering as a creation of pair of positive and negative energy states, the latter representing the final state. One can characterize precisely the deviations of this Eastern world view with respect to the Western world view assuming an objective reality with a positive definite energy and understand why the Western illusion apparently works. In the case of TQC the initial *resp.* final state of braided anyon system would correspond to positive *resp.* negative energy state.

The light-like boundaries of magnetic flux tubes are ideal for TQC. The point is that 3-dimensional light-like quantum states can be interpreted as representations for the time evolution of a two-dimensional system and thus represented self-reflective states being "about something". The light-likeness (no geometric time flow) is a space-time correlate for the ceasing of subjective time flow during macro-temporal quantum coherence. The S-matrices of TQC can be coded to these light-like states such that each elementary braid operation corresponds to positive energy anyons near the boundary of the magnetic flux tube A and negative energy anyons with opposite topological charges residing near the boundary of flux tube B and connected by braided threads representing the quantum gate. Light-like boundaries also force Chern-Simons action as the only possible general coordinate invariant action since the vanishing of the metric determinant does not allow any other candidate. Chern-Simons action indeed defines the modular functor for braid coding for a TQC program.

The comparison of the concrete model for TQC in terms of magnetic flux tubes with the structure of DNA gives tantalizing hints that DNA double strand is a topological quantum computer. Strand *resp.* conjugate strand would carry positive *resp.* negative energy anyon systems. The knotting and linking of DNA double strand would code for 2-gates realized as a unique maximally entangling Yang-Baxter matrix R for 2-state system. The pairs A-T, T-A, C-G, G-C in active state would code for the four braid operations of 3-braid group in 1-qubit Temperley Lieb representation associated with quantum group $SL(2)_q$. On basis of this picture one can identify N-O hydrogen bonds between DNA strands as structural correlates of 3-braids responsible for the nontrivial 1-gates whereas N-N hydrogen bonds would be correlates for the return gates acting as identity gates. Depending on whether the nucleotide is active or not it codes for nontrivial 1-gate or for identity gate so that DNA strand can program itself or be programmed dynamically.

The more recent work has demonstrated the the particular physical realization discussed in this chapter is only one possibily, and that braiding naturally generalizes to 2-braiding in TGD framework with braiding defined for string world sheets in 4-D space-time. Zero energy ontology allows also to understand why TQC programs - naturally identiable as biological programs - are selected as those associated with the maxima of Kähler function, which are now space-time surfaces rather than 3-surfaces.

DNA as Topological Quantum Computer

The chapter represents a vision about how DNA might act as a topological quantum computer). TQC means that the braidings of braid strands define TQC programs and M-matrix (generalization of S-matrix in zero energy ontology) defining the entanglement between states assignable to the

end points of strands define the TQC usually coded as unitary time evolution for Schrödinger equation.

Before a representation of the model of TQC general vision about what happens in quantum jump, which at least in formal sense can be regarded as quantum computation (TQC), is represented. Included is also a section about possible modification of thermodynamics required by the possibility of negentropic entanglement. The modification corresponds simply to the replacement $S \to S - N$ for the entropy in standard thermodynamics. The implications of this replacement are however highly non-trivial. The "pessimistic" generalization of the second law allows to understand the thermodynamical aspect of TQC. One can understand why living matter is so effective entropy producer as compared to inanimate matter and also the characteristic decomposition of living systems to highly negentropic and entropic parts as a consequence of generalized second law. ADP-ATP process of metabolism provides a concrete application for the generalized thermodynamics and allows to see this process as a transfer of negentropic entanglement. Also DNA double strand for which sugar-phosphate backbone consists of XMPs, X= A,T,C,G containing negentropy carrying phosphate bonds can be seen as analogous to conscious brain with DNA strands representing right and left hemispheres.

One can end up to the model of TQC in the following manner.

1. Darwinian selection for which the standard theory of self-organization provides a model, should apply also to TQC programs. Tqc programs should correspond to asymptotic self-organization patterns selected by dissipation in the presence of metabolic energy feed. The spatial and temporal pattern of the metabolic energy feed characterizes the TQC program - or equivalently - sub-program call.

2. Since braiding characterizes the TQC program, the self-organization pattern should correspond to a hydrodynamical flow or a pattern of magnetic field inducing the braiding. Braid strands must correspond to magnetic flux tubes of the magnetic body of DNA. If each nucleotide is transversal magnetic dipole it gives rise to transversal flux tubes, which can also connect to the genome of another cell. As a matter fact, the flux tubes would correspond to what I call wormhole magnetic fields having pairs of space-time sheets carrying opposite magnetic fluxes.

3. The output of TQC sub-program is probability distribution for the outcomes of state function reduction so that the sub-program must be repeated very many times. It is represented as four-dimensional patterns for various rates (chemical rates, nerve pulse patterns, EEG power distributions,...) having also identification as temporal densities of zero energy states in various scales. By the fractality of TGD Universe there is a hierarchy of TQCs corresponding to p-adic and dark matter hierarchies. Programs (space-time sheets defining coherence regions) call programs in shorter scale. If the self-organizing system has a periodic behavior each TQC module defines a large number of almost copies of itself asymptotically. Generalized EEG could naturally define this periodic pattern and each period of EEG would correspond to an initiation and halting of TQC. This brings in mind the periodically occurring sol-gel phase transition inside cell near the cell membrane. There is also a connection with hologram idea: EEG rhythm corresponds to reference wave and nerve pulse patters to the wave carrying the information and interfering with the reference wave.

4. Fluid flow must induce the braiding which requires that the ends of braid strands must be anchored to the fluid flow. Recalling that lipid mono-layers of the cell membrane are liquid crystals and lipids of interior mono-layer have hydrophilic ends pointing towards cell interior, it is easy to guess that DNA nucleotides are connected to lipids by magnetic flux tubes and hydrophilic lipid ends are stuck to the flow.

5. The topology of the braid traversing cell membrane cannot be affected by the hydrodynamical flow. Hence braid strands must be split during TQC. This also induces the desired magnetic isolation from the environment. Halting of TQC reconnects them and make possible the communication of the outcome of TQC.

There are several problems related to the details of the realization.

1. How nucleotides A,T,C,G are coded to the strand color and what this color corresponds to physically? There are two options which could be characterized as fermionic and bosonic.

   (a) Magnetic flux tubes having quark and anti-quark at their ends with u,d and u_c, d_c coding for A,G and T,C. CP conjugation would correspond to conjugation for DNA nucleotides.

   (b) Wormhole magnetic flux tubes having wormhole contact and its CP conjugate at its ends with wormhole contact carrying quark and anti-quark at its throats. The latter are predicted to appear in all length scales in TGD Universe.

2. How to split the braid strands in a controlled manner? High T_c super conductivity suggests a possible mechanism: braid strand can be split only if the supra current flowing through it vanishes. A suitable voltage pulse induces the supra-current and its negative cancels it. The conformation of the lipid could control whether it it can follow the flow or not. The absence of both genuine magnetic monopoles and boundaries however demands that the monopole flux tubes must be closed. One manner to achieve this is to assume that the magnetic flux returns back along second space-time sheet.

   A more realistic variant of this model is based on pairs of flux tubes going through the membrane and carrying opposite currents and parallel (opposite) magnetic fields. Reconnection for the members of the pair occurring the cell membrane effectively cuts both. This conforms with the identification of Cooper pairs as $S = 0$ or $S = 1$ states of electrons at the two flux tubes. The reconnection occurs naturally at the limit when the velocity of electrons and thus current goes to zero.

3. How magnetic flux tubes can be cut without breaking the conservation of the magnetic flux? The notion of wormhole magnetic field could save the situation now: after the splitting the flux returns back along the second space-time sheet of wormhole magnetic field. An alternative solution is based on reconnection of flux tubes. Since only flux tubes of same color can reconnect this process can induce transfer of color: "color inheritance": when applied at the level of amino-acids this leads to a successful model of protein folding. Reconnection makes possible breaking of flux tube connection for both the ordinary magnetic flux tubes and wormhole magnetic flux tubes.

4. How magnetic flux tubes are realized? The interpretation of flux tubes as correlates of directed attention at molecular level leads to concrete picture. Hydrogen bonds are by their asymmetry natural correlates for a directed attention at molecular level. Also flux tubes between acceptors of hydrogen bonds must be allowed and acceptors can be seen as the subjects of directed attention and donors as objects. Examples of acceptors are aromatic rings of nucleotides, O = atoms of phosphates, etc.. A connection with metabolism is obtained if it is assumed that various phosphates XMP, XDP, XTP, $X = A, T, G, C$ act as fundamental acceptors and plugs in the connection lines. The basic metabolic process $ATP \to ADP + P_i$ allows an interpretation as a reconnection splitting flux tube connection, and the basic function of phosphorylating enzymes would be to build flux tube connections as also of breathing and photosynthesis.

The rest of the article represents a more concrete vision about how DNA might act as a topological quantum computer (TQC). The topics discussed are following.

1. How the basic gates are realized concretely? Gates can be identified as basic braid operations so that the question reduces to how braidings of magnetic flux tubes represent gates and what kind of particles represent the quantum states. The identification of the particles is in terms of quarks: TGD indeed predicts a hierarchy of scaled variants of hadron physics.

2. How the braiding is realized? What do braid strands identified as magnetic flux tubes look like? How the braiding operation is induced? The tentative answer is that color magnetic flux tubes connecting DNA nucleotides to the lipids of nuclear and cell membrane define braid strands and that braiding operations are induced by hydrodynamic flow around membrane generating 2-D flow of liquid crystal defined by the lipids. Also nerve pulse propagation can induced this kind of 2-D flow.

3. How magnetic flux tubes are realized? The interpretation of flux tubes as correlates of directed attention at molecular level leads to concrete picture. Hydrogen bonds are by their asymmetry natural correlates for a directed attention at molecular level. Also flux tubes between acceptors of hydrogen bonds must be allowed and acceptors can be seen as the subjects of directed attention and donors as objects. Examples of acceptors are aromatic rings of nucleotides, O = atoms of phosphates, etc.. A connection with metabolism is obtained if it is assumed that various phosphates XMP, XDP, XTP, $X = A, T, G, C$ act as fundamental acceptors and plugs in the connection lines. The basic metabolic process $ATP \to ADP + P_i$ allows an interpretation as a reconnection splitting flux tube connection, and the basic function of phosphorylating enzymes would be to build flux tube connections as also of breathing and photosynthesis.

The model is certainly very speculative and heavily relies on the new physics predicted by TGD. One can also imagine alternative scenarios. The model makes however strong predictions and is therefore testable.

1. The model makes several testable predictions about DNA itself. In particular, matter-antimatter asymmetry and slightly broken isospin symmetry have counterparts at DNA level induced from the breaking of these symmetries for quarks and antiquarks associated with the flux tubes. DNA cell membrane system is not the only possible system that could perform TQC like activities and store memories in braidings: flux tubes could connect biomolecules and the braiding could provide an almost definition for what it is to be living. Even water memory might reduce to braidings.

2. The model leads also to an improved understanding of other roles of the magnetic flux tubes containing dark matter. Phase transitions changing the value of Planck constant for the magnetic flux tubes could be key element of bio-catalysis and electromagnetic long distance communications in living matter. For instance, one ends up to what might be called code for protein folding and bio-catalysis. There is also a fascinating connection with Peter Gariaev's work suggesting that the phase transitions changing Planck constant have been observed and wormhole magnetic flux tubes containing dark matter have been photographed in his experiments.

3. In the proposed vision genes define the hardware and TQC programs the software responsible for what becomes cultural evolution at the higher levels of evolutionary hierarchy. This vision explains also the mystery of introns. The quite recent findings challenging genetic determinism expressed using the term "genetic dark matter" provide support for an existence of new information carrying level at the level of genome identifiable in terms of TQC programs.

It must be emphasized that this model of DNA as TQC is only one option among many. There is large flexibility concerning the identification of fermions involved. For instance A,T,C,G could be represented also in terms of 4 states assignable to two spin half fermions at parallel flux tubes. This would give rise to high T_c superconductor with both $S = 0$ ($S = 1$) Cooper pairs assignet to flux tubes with opposite (parallel) magnetic fields. The spin-spin interaction energy for the Cooper pair would be negative and proportional to h_{eff} and same for all fermion pairs if $h_{eff} = h_{gr}$ hypothesis holds true at microscopic level.

The Notion of Wave-Genome and DNA as Topological Quantum Computer

Peter Gariaev and collaborators have reported several strange effects of laser light and also ordinary light on DNA. These findings include the rotation of polarization plane of laser light by DNA, phantom DNA effect, the transformation of laser light to radio-wave photons having biological effects, the coding of DNA sequences to the modulated polarization plane of laser light and the ability of this kind of light to induce gene expression in another organisms provided the modulated polarization pattern corresponds to an "address" characterizing the organism, and the formation of images of what is believed to be DNA sample itself and of the objects of environment by DNA sample in a cell irradiated by ordinary light in UV-IR range.

In this chapter a TGD based model for these effects is discussed. A speculative picture proposing a connection between homeopathy, water memory, and phantom DNA effect is discussed

and on basis of this connection a vision about how the tqc hardware represented by the genome is actively developed by subjecting it to evolutionary pressures represented by a virtual world representation of the physical environment. The speculation inspired by this vision is that genetic code as well as DNA-, RNA- and amino-acid sequences should have representation in terms of nuclear strings. The model for dark baryons indeed leads to an identification of these analogs and the basic numbers of genetic code including also the numbers of aminoacids coded by a given number of codons are predicted correctly. Hence it seems that genetic code is universal rather than being an accidental outcome of the biological evolution.

Quantum Gravitation and Topological Quantum Computation

In this article the connection of quantum gravitation, as it is understood in the TGD framework, with topological quantum computation (TQC) is considered. I sketched the first TGD based vision about DNA as a TQCer for about 13 years ago. In particular, a model of the system consisting of DNA and nuclear/cell membrane system acting as a TQCer was discussed.

TGD has evolved a lot after this and there are several motivations for seeing what comes out from combining the recent view about quantum TGD and TGD inspired quantum biology with this model.

1. There is a rather detailed view about the role of dark matter as phases of ordinary matter with the effective Planck constant $h_{eff} = nh_0$. Large values of h_{eff} allow to overcome the problems due to the loss of quantum coherence.

   This leads to the notion of the dark DNA (DDNA), whose codons are realized as dark proton triplets and proposed to accompany the ordinary DNA. Also dark photon triplets are predicted and one ends up to a model of communications and control based on dark cyclotron resonance in which codons serve as addresses and modulation of the signal frequency scale codes the signal to a sequence of pulses. Nerve pulses could be one application.

2. Quite recently, also the understanding of the possible role of quantum gravitation in biochemistry, metabolism, bio-catalysis, and in the function of DNA has considerably increased. The gravitational variants of hydrogen bonds and valence bonds between metal ions having very large value of $h_{eff} = h_{gr}$, where $h_{gr} = GMm/v_0$ is the gravitational Planck constant originally introduced by Nottale, are in a key role in the model and explain metabolic energy quantum as gravitational energy liberated when dark protons "drops" from a very long gravitational flux tube in the transition $h_{gr} \to h$. Also electronic metabolic energy quantum is predicted and there is empirical support for this.

3. A further motivation comes from the number theoretic vision of quantum TGD. Galois groups as symmetry groups represent new physics and the natural questions are whether Galois groups could give rise to number theoretic variants of anyons and what could the TGD counterparts of the condensed matter (effective) Majorana electrons proposed by Kitaev as anyon like states?

   The answer is that quantum superpositions of symmetric hydrogen bonded structures of form X..H-H+X-H...X are excellent candidates for the seats of dark ($h_{eff} > nh_0 > h$) bi-localized electrons defining TGD analogs of condensed matter Majorana electrons.

   The Galois groups permute the roots of a polynomial, which determines a space-time region by $M^8 - H$ duality. The roots correspond to mass squared values, in general algebraic numbers, and thus to mass hyperboloids in $M^4_c \subset M^8_c$. The H images correspond to 3-hyperboloids with a constant value $a = a_n$ of light-cone proper time. Therefore the Galois group can permute points with time-like separation. Note however that the real or rational parts of two values of a can be same.

   This looks very strange at first but actually confirms with the fact that time-like braidings defining TQC correspond in TGD time-like braidings (involving also reconnections) of string like objects defining string world sheets, which are not now time evolutions of space-like entities as physical state but correspond to time-like entities defining boundary data necessary for fixing holography completely. Their presence is forced by the small failure of the determinism of the action principle involved and is completely analogous to the non-determinism for soap films with frames serving as seats for the failure of determinism.

4. Braidings appear therefore at the level of fundamental TGD and correspond to string world sheets. They are possible only in 4-D space-time but not in string models.

   Also TQC-like processes appear automatically at the level of fundamental physics. In particular, the number theoretical state function reduction cascade for the Galois group following the time evolution induced by braiding can be regarded as a generalization of a decomposition of integers to primes: now primes are replaced by simple groups defining primes for finite groups. Nature is doing number theory!

5. Also zero energy ontology (ZEO) brings in new elements. The change of the arrow of time in "big" state function reductions (BSFRs) implies that dissipation with a reversed arrow of time provides an automatic error correction procedure. Also TQC in which the arrow of time varies for sub-modules, can be considered.

The Possible Role of Spin Glass Phase and P-Adic Thermodynamics in Topological Quantum Computation: the TGD View

Topological quantum computation (TQC) or more generally, a TQC-like process (to be referred as TQC), is one possible application of TGD. The latest article summarizes the recent number theoretic view about TQC in TGD inspired biology. There are several new physics elements involved. Mention only the notion of many-sheeted space-time involving the notions of electric and magnetic body; the new view about quantum theory relying on the $M^8 - H$ duality relating number theoretic and geometric views about physics and predicting the hierarchy of effective Planck constants assignable to a hierarchy of extensions of rationals; cognitive representations as unique discretization of space-time surface realizing generalized quantum computationalism; and zero energy ontology (ZEO) suggesting a new vision about quantum error correction. Quantum gravitation plays a key role in the proposal.

The engineering aspects of TQC were not discussed. The question that inspired this article was whether classical computation which relies strongly on non-equilibrium thermodynamics, could provide guidelines to end up with a more detailed view.

This led to a proposal in which p-adic thermodynamics assigned with the TGD based description of spin glasses would play a key role. TQC would involve quantum annealing in the spin glass energy landscape for the fermion states associated with flux tube structures. Anyons would be replaced with representations of the Galois group.

Physical states are however Galois singlets and many fermion states would involve entanglement between irreps of (relative) Galois group associated with spin *resp.* momentum degrees of freedom and give rise to a superposition of Galois singlets. The state function reduction ending TQC would project a tensor product of a given irrep from this superposition.

The entanglement between representations should be engineered in such a manner that the desired outcome of TQC would have the largest entanglement probability. p-Adic thermodynamics could give the entanglement probabilities. A connection with the travelling salesman problem emerges besides the connection with the factorization of the Galois group to prime factors appearing as relative Galois groups, which are simple (prime).

1.6.2 PART II: TGD INSPIRED MODELS FOR GENOME

Genes and Memes

In this article basic TGD inspired ideas about genetic code are discussed.

1. Genetic and memetic code from the model of abstraction process

The basic numbers of genetic code are probably not accidental. This led for more than two decades ago to an attempt to construct a model for abstraction process reproducing the basic numbers of the genetic code. The simplest model for an abstraction process is based on a repeated formation of statements about statements starting from two basic statements. If one drops at each step of the construction the statement corresponding to empty set in the set theoretic realization of Boolean algebra, one obtains a hierarchy allowing to understand the basic numbers of genetic code, including the number of amino-acids. What one obtains is so called Combinatorial Hierarchy consisting of the Mersenne numbers $2, M(1) = 3, 7$,$127, 2^{127} - 1, ..$ constructed using the rule $M(n+1) = M_{M(n)} = 2^{M(n)} - 1$. The explicitly listed ones are known to be primes. Combinatorial

Hierarchy emerges from a model of abstraction process as subsequent transitions from level to meta level by forming Boolean statements about Boolean statements of level n and dropping one statement away.

The infinite hierarchy of possible genetic codes suggests the possibility of an infinite hierarchy of increasingly complex life-forms. The natural question is whether a counterpart of the genetic code could make sense for our ideas, memes. Combinatorial Hierarchy model for abstraction process predicts that memetic code should correspond to the level M_{127} of the hierarchy. This leads to a precise realization of the memetic code in terms of binary sequences. Codewords, counterparts of mRNA, correspond to 126-bit sequences. Also almost-127-bit code with $2^{127}-1$ codons is possible.

2. Frequency and pulse representations of codes

p-Adic length scale hypothesis and identification of codes as special cases of a hierarchy of p-adic cognitive codes allows quantitative predictions. The most general assumption assigns to any prime $p \simeq 2^k$, k integer, a hierarchy of cognitive codes with codeword having a duration equal to n-ary p-adic time scale $T_p(n)$ such that the number of bits is factor k_1 of k. Codewords could be realized either as k_1 harmonics of the fundamental frequency $f_p(n) = 1/T_p(n)$ or as temporal sequences of bits of duration $\tau = T_p(n)/k_1$ represented as pulses of maximal duration τ. Pulse-frequency dichotomy corresponds to dichotomies like particle-wave, nerve pulse-EEG, and talking left brain-singing right brain.

Genetic code would correspond to $k = 2^7 - 1 = 127$ and have 6 bits (64 DNA triplets). These codewords could be realized dynamically as temporal field patterns. For genetic code primes $p \simeq 2^k$, $k = 6 \times n$ define candidates for the duration of the genetic code word if all factors of k are assumed to define a possible number of bits of the code word. The time scales come as powers of 8 so that they cover the entire range of biologically relevant time scales down to CP_2 length scale, and genetic code could appear as fractally scaled versions unlike memetic code and perhaps also outside the biological context. $k = 2 \times 126 = 2 \times 6 \times 21 = 252$ allows the representation of both 126-bit memetic codeword, 6-bit genetic codeword, and almost-7-bit genetic code word. For pulse representation genetic codon would have a duration of 50 ms whereas the bit would have duration of 8.3 ms so that the realization using nerve pulse patterns is in principle possible. Frequency representation would be realized as 6 first harmonics of the fundamental frequency $f_1 = 2^n \times 20$ Hz, where $f_1 = 20$ Hz defines the lower end of audible frequency range and also the rate for the translation of mRNA triplets to amino-acids. 126-bit memetic code allows a representation as sequence of 21 nerve pulses of duration 2.4 ms each of them accompanied by 6-bit genetic codon realized at the microtubular level (this representation of genetic code has been suggested by Koruga).

The secondary p-adic time scale associated with M_{127} is .1 seconds and defines the duration of the almost 127-bit memetic codeword. For frequency representation is realized as 127 first harmonics of $f_1 = 10$ Hz and the duration of the bit for pulse representation is .8 ms which is shorter than the duration of nerve pulse. The duration .1 seconds of code word might be identified as the minimal duration of cortical mental images, and the so called features introduced by Walter Freeman could define pulse representation of memetic code words of 127 bits. The highest frequency in the frequency representation is 1270 Hz and could define the frequency responsible for synchronous neuronal firing known to be about 1 kHz. Various numerical co-incidences suggest that language corresponds to a particular realization of memetic and genetic codes closely related to their realization at DNA level.

3. Model for the evolution of genetic code from the symmetries of the code

TGD leads to a model for the evolution of the genetic code motivated by the observation that the genetic code possesses an exact A-G and almost exact T-C permutation symmetry with respect to the third nucleotide of the DNA triplet. This leads to the hypothesis that genetic code has evolved as a fusion of doublet and singlet codes accompanied by a small breaking of the product symmetry. The hypothesis is highly predictive, and it is possible to reproduce genetic code and its variants by this mechanism in a natural manner. The mechanism has deep implications for the models of the bio-chemical evolution before genetic code: in particular a detailed model for the evolution of genetic code and pre-biotic evolution emerges.

4. Mapping memetic code to 169-bit micro-tubular code

169-bit micro-tubular code words is excellent candidate for a representation of long term memories as a temporal list of activated memes. The model for the mapping of memetic code to 169-bit microtubular code is dictated by the general ideas about realization of intentions and

p-adic cognitive codes. When combined with general number theoretical arguments and physical considerations the model becomes highly unique. The prediction for the intronic representation of the memetic codon involving 9 DNA triplets as parity bits is readily testable, and also the prediction for the microtubular electric field pattern is in principle testable.

5. Genes, memes, and universal language

Also static representations of the memetic code are possible and intronic DNA could provide representation of memetic codewords as sequences of 21 DNA triplets. At DNA level memes and genes should relate like computer software and hardware. In the case of language the rules producing a given linguistic expression can be seen as the high level software, main programs, whereas words can be seen as hardware-like lower level subprograms. This leads to the idea that memetic codewords define the basic program modules producing linguistic expressions by activating genes which express themselves in terms of field patterns generating nerv pulse patterns generating words or word sequences very much analogous to proteins.

Time mirror mechanism and the structure of the computer language LISP inspire a concrete model for memes as intronic programs initiated from magnetic body and calling genes as subprograms in turn calling other genes as subprograms and generating at the lowest level field patterns generating nerve pulses patterns giving rise to the motor action producing speech. Phonemes could directly correspond to DNA triplets and define the basic building blocks of language having as such no meaning. If this view is correct, the development of spoken and written language would mean basically the emergence of a higher level of intentionality, which utilizes an already existing repertoire of memes expressed in many other manners. This would in turn suggest that animals and even plants possess some kind of languages realized at cellular level, and that even inter-species communications using common memetic grammar and genetic vocabulary.

6. Corals and men

A strong support for the idea of interspecies communications come from the sensational finding that the genome of corals, known to be the most primitive animals having nervous system, share a large number of common genes with vertebrates whereas they share much less common genes with flies and worms. This finding challenges profoundly the existing view about the evolution of animals and adds a further mystery to the halo of mysteries surrounding Cambrian explosion.

Since corals are usually regarded as relatively simple creatures, the most obvious questions concern the function of the complex genome. The TGD inspired answer is that the common genes provide a common vocabulary making possible communications between corals and vertebrates such as fishes. The genes express themselves in terms of electromagnetic field patterns and cyclotron transitions of Ca_{++} ions giving rise to primitive EEG are crucially involved. The calcium containing skeleton possessed by both corals and vertebrates could amplify the field patterns representing genes and make possible interspecies communications.

Coral reefs can be also seen as super organisms with cells replaced by double cell layers forming the corals. This forces to consider the possibility that coral reefs are super-organisms perhaps even possessing super-neural system consisting of super-neurons defined by differentiated corals. Accordingly, in TGD Universe coral reefs could be seen as descendants of higher level intra-terrestrial life forms which boosted Cambrian explosion by horizontal transfer of genes to much simpler life forms and providing also them with a nervous system.

7. Does ontogeny recapitulate also the future phylogeny at the level of genes and memes?

Ontogeny recapitulates phylogeny means that the morphogenesis of the embryo repeats the evolutionary steps leading to the organism. One might ask whether and how this process is realized at the level of genes and memes (introns expressing themselves electromagnetically): this could provide further understanding of the mysterious "junk DNA". Combining this question with some recent puzzling findings leads to a rather radical revision of the view about evolution proceeding through random mutations.

1. The second strange finding besides coral genome reported in New Scientist (5 June, 2004) was that the removal of large portions of conserved intronic DNA from mice has no detectable effects on the basic biological functions. Conserved parts of DNA are usually thought as being an outcome of a long selection process and far from genetic trash. This could be understood if the conserved introns have been radiated from corals and the selection process has occurred already before the Cambrian explosion induced by the emergence of the corals and leading to the sudden emergence of new highly developed life forms. That mouse introns did not have

any identifiable function could mean that they are still waiting for time to become ripe for their expression.

2. A third strange discovery relates to morphogenesis and is known as Ciba Geigy effect. Chemists Guido Ebner and Guido Schuerch exposed germs, seeds, and eggs to an electric field with strength in the range .5-2 kV/m. For instance, the resulting trouts appeared to resemble their ancient predecessors. The leaves of certain plants represented a series of snapshots from evolution with the oldest leaves dating back to 300 million years. This suggests that the memone and genome represent ontogeny recapitulates phylogeny principle quite concretely, and that static electric fields could provide the practical manner to activate and study the ancient morphologies. Even partial transmutation of life forms to each other might be possible (beautiful swan to ugly duckling at least!). The activation of morphologies not yet realized is probably more difficult: new memetic programs require new genetic hardware.

The resulting vision about evolution of higher organisms would be as the activation of conserved memes and genes basically inherited from corals rather than by the emergence of new genes by random mutations. Very much like learning new features of a text processing program. The explosive evolution of human civilization could correspond to a rapid shift of the activated portion of memone and genome. The fact that 95 per cent of our DNA consists of introns suggests that an enormous evolutionary potential exists also at the level of personal evolution during single life cycle. TGD view about space-time as a 4-dimensional living organism would mean that this personal evolution continues after the biological death since the 4-body of geometric past does not disappear in the biological death.

Many-Sheeted DNA

The problems of how genes code information about the morphology of organism and how this information is expressed, belong to the great puzzles of the developmental biology. A closely related mystery is the differentiation of cells. The notion of the genetic program is far from precise and it is not clear how close the analogy with a computer program is. There are also several problems which challenge the basic dogmas of genetics.

1. Only 1 per cent of DNA of human genome actually codes polypeptides. Eukaryote genes contain intron sequences which are transcribed into hnRNA but snipped of when hnRNA is transformed mRNA in process called slicing. The higher the evolutionary level of organism, the higher the fraction of introns is. Molecular Darwinists see introns as "junk DNA" but there is evidence that introns are far from junk. For instance, the splicing of intron contribution from hnRNA to give mRNA can give several different outcomes depending on the stage of development of the organism and introns are crucial for the effectiveness of immune system. Hence one can wonder whether intronic mRNA and protein mRNA could both form the real output of gene subprograms serving in some sense as input for other gene subprograms. This interpretation obviously conflicts with "gene-single protein" dogma in its basic form.

2. There are large amounts of highly repetitive DNA which is silent. One can wonder whether there is some fundamental mis-understanding involved. Could it be that this DNA is analogous to control DNA not transcribed to RNA and therefore not all useless. There is also active repetitive DNA.

3. There is large amount of silent DNA in control sections between genes. Could it be that this silent DNA expresses itself in some nonchemical manner? Chemical expression is very slow, translation rate being twenty aminoacids per second, and one can wonder whether life might have invented faster modes of gene expression and control of gene expression.

4. Plant genome is often by a factor of hundred longer than human genome. One could argue that the complexity of organism is measured by the length of the shortest program coding the organism. It is however not at all obvious how the genome of plants could be more redundant than human genome since repetitive sequences common to all animals are present. Introns are in fact more frequent in human genome. This suggests that some new unidentified degrees

of freedom giving rise to complexity might be present and that the chemistry of DNA in the sense of standard physics is perhaps not all that is needed to understand genetic program.

5. Various self-organization processes such as self-assembly and de-assembly are very frequent in living systems. The problem how genes give rise to morphology of the organism is poorly understood. This forces to challenge the dogma of genetic determinism. One should be able to understand what is determined by genes and what is determined by self-organization and whether the genes of the standard physics are enough.

The reason why the above mentioned problems have turned out to be so untractable might be due to a wrong view about space-time. Many-sheeted space-time concept of TGD might be absolutely crucial for the expression of genetic code. Gene itself might be many-sheeted space-time structure coding faithfully the topology of the expression domain of gene. This many-sheeted structure of DNA could allow to understand the miraculous looking features of DNA replication and cell differentiation. TGD based view of evolution as p-adic evolution implied by the basic quantum theory, should be a crucial element of the picture. Together with p-adic length scale hypothesis, with Combinatorial Hierarchy model for genetic code allowing to interpret genes as Boolean statements, and general vision about quantum control and coordination based on a hierarchy of weakly coupled super conductors, the notion of many-sheeted DNA leads to precise quantitative predictions and a general model for genetic program. In particular, one can understand the mystery of introns. What interesting from the point of view of our consciousness is that it might be possible to interpret the Boolean statements represented by the exon and intron parts of genes as a physical representation for our belief system. Thus genes would code both matter– and mind like hardware of the living system.

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 vision about dark matter hierarchy labelled partially by a hierarchy of values of effective Planck constant coming as integer multiples of the ordinary Planck constant leads to a rather concrete view about the hierarchy of magnetic bodies and implies a natural generalization leading to the notion of super- and hyper genes. The original model assumption $\hbar_{eff} = \lambda^{k_d}\hbar_0$, $\lambda \simeq 2^{11}$, is however un-necessarily strong.

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

Model for the Findings about Hologram Generating Properties of DNA

A TGD inspired model for the strange replica structures observed when DNA sample is radiated by red, IR, and UV light using two methods by Peter Gariaev and collaborators. The first method produces what is tentatively interpreted as replica images of either DNA sample or of five red lamps used to irradiate the sample. Second method produce replica image of environment with replication in horizontal direction but only at the right hand side of the apparatus. Also a white phantom variant of the replica trajectory observed in the first experiment is observed and has in vertical direction the size scale of the apparatus.

A model is developed in order to explain the characteristic features of the replica patterns. The basic notions are magnetic body, massless extremal (topological light ray), the existence of Bose-Einstein condensates of Cooper pairs at magnetic flux tubes, and dark photons with large value of Planck constant for which macroscopic quantum coherence is possible. The hypothesis is that the first method makes part of the magnetic body of DNA sample visible whereas method II would produce replica hologram of environment using dark photons and produce also a phantom image of the magnetic tubes becoming visible by method I. Replicas would result as mirror hall effect in the sense that the dark photons would move back and forth between the part of magnetic body becoming visible by method I and serving as a mirror and the objects of environment serving

also as mirrors. What is however required is that not only the outer boundaries of objects visible via ordinary reflection act as mirrors but also the parts of the outer boundary not usually visible perform mirror function so that an essentially 3-D vision providing information about the geometry of the entire object would be in question. Many-sheeted space-time allows this.

The presence of the hologram image for method II requires the self-sustainment of the reference beam only whereas the presence of phantom DNA image for method I requires the self-sustainment of both beams. Non-linear dynamics for the energy feed from DNA to the magnetic body could make possible self-sustainment for both beams simultaneously. Non-linear dynamics for beams themselves could allow for the self-sustainment of reference beam and/or reflected beam. The latter option is favored by data.

Quantum Model for Remote Replication

A model for remote replication of DNA is proposed. The motivating experimental discoveries are phantom DNA, the evidence for remote gene activation by scattered laser light from similar genome, and the recent findings of Montagnier's and Gariaev's groups suggesting remote DNA replication.

Phantom DNA is identified as dark nucleon sequences predicted by quantum TGD with dark nucleons defining naturally the analogs of DNA, RNA, tRNA, and amino-acids and realization of vertebrate genetic code. The notion of magnetic body defining a hierarchy of flux quanta realize as flux tubes connecting DNA nucleotides contained inside flux tubes connecting DNA codons and a condensed at flux sheets connecting DNA strands is an essential element of the model. Dark photons with large value of Planck constant coming as integer multiple of ordinary Planck constant propagate along flux quanta connecting biomolecules: this realizes the idea about wave DNA. Biomolecules act as quantum antennas and those with common antenna frequencies interact resonantly.

Biomolecules interacting strongly - in particular DNA nucleotides- would be characterized by same frequency. An additional coding is needed to distinguish between nucleotides: in the model for DNA as topological quantum computer quarks (u,d) and their antiquarks would code for the nucleotides A,T,C, and G would take care of this. The proposed role of quarks in biophysics of course makes sense only if one accepts the new physics predicted by quantum TGD. DNA codons (nucleotide triplets) would be coded by different frequencies which correspond to different values of Planck constant for photons with same photon energy propagating along corresponding flux tubes. This allows to interpret the previously proposed TGD based realization of so called divisor code proposed by Khrennikov and Nilsson in terms of quantum antenna mechanism. Years later from this proposal a much more detailed mode emerged leading to a formula for $h_{eff} = n \times h$ making h_{eff} proportional to the mass (number) of the charged particle involved. This predicts universal energy spectrum for dark photons in the range of visible and UV photons. Dark photons can transform to ordinary ones in energy conserving manner and the outcome is identified as biophotons.

In this framework the remote replication of DNA could be understood. DNA nucleotides interact resonantly with DNA strand and attach to the ends of the flux tubes emerging from DNA strand and organized on 2-D flux sheets. In Montagnier's experiment the interaction between test tubes A and B would be mediated by dark photons between DNA and dark nucleon sequences and amplify the dark photon beam, which in turn would induce remote replication. In the experiment of Gariaev scattered laser light would help to achieve the same purpose. Dark nucleon sequences would be generated in Montagnier's experiment by the homeopathic treatment of the test tube B.

Dark nucleon sequences could characterize the magnetic body of any polar molecule in water and give it a "name" written in terms of genetic codons so that genetic code would be much more general than usually thought. The dark nucleon sequence would be most naturally assigned with the hydrogen bonds between the molecule and the surrounding ordered water being perhaps generated when this layer of ordered water melts as the molecule becomes biologically active. Water memory and the basic mechanism of homeopathy would be due to the "dropping" of the magnetic bodies of polar molecules as the water is treated homeopathically and the dark nucleon sequences could define an independent life form evolving during the sequence of repeated dilutions and mechanical agitations taking the role environmental catastrophes as driving force of evolution. The association of DNA, RNA and amino-acid sequences associated with the corresponding dark nucleon sequences

would be automatic since also also they are polar molecules surrounded by ordered water layers.

The transcription of the dark nucleon sequences associated the with the polar invader molecule to ordinary DNA sequences in turn coding of proteins attaching to the invader molecules by the quantum antenna mechanism could define the basic mechanism for functioning and evolution of the immune system.

Part I

TOPOLOGICAL QUANTUM COMPUTATION IN TGD UNIVERSE

Chapter 2

About the New Physics Behind Qualia

2.1 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.

2.1.1 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: $h_{eff} = n \times h$ [K110, **?**]. 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.

2.1.2 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 [J20, J21]. 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 [K35].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 [I106] provide support for the resulting general vision.

2.1.3 Mind Like Space-Time Sheets As Massless Extremals

Mind like space-time sheets are the geometric correlates of selves. So called massless extremals (MEs) [K68] 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").

2.1.4 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 [K92]. 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 [C5, C2] would represent one particular example of this kind of exotically ionized nucleus [K92]. 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 [K36].

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 [K80] and Ca^{2+} waves [K47, K51] would represent examples of physiological correlates of this quantum control.

2.1.5 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 [K38]. 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 [K35] 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 [K106].

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.

2.1.6 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 [K95] led however to a definite progress in this respect [K66].

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 [K95] 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` [L19].

2.2 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.

2.2.1 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 [K105].

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) [K73] 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`) [E1] 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 $v_0 < 1$.

2.2.2 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 [K111] 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.

2.2.3 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 $\hbar \to k\hbar$ 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.

2.2.4 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 $\alpha_K \to \alpha_K/n$ induced by the scaling $\hbar_0 \to n\hbar_0$.

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.

2.2.5 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 $g^{\alpha\beta}_{eff}$ 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: $g^{kl}_{eff} = K^2 m^{kl}$.

   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

$$g^{\alpha\beta}_{eff} p_\alpha p_\beta = g^{\alpha\beta}_{eff} \partial_\alpha h^k \partial_\beta h^l p_k p_l \equiv g^{kl}_{eff} p_k p_l = n^2 \frac{\hbar^2}{L^2} \quad . \tag{2.2.1}$$

   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. $g^{kl}_{eff} = K^2 m^{kl}$ 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

$$p_{gr} = \frac{GMm}{v_0}\frac{1}{L} \quad . \tag{2.2.2}$$

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:

$$g^{\alpha\beta}_{eff} L_\alpha L_\beta = g^{kl}_{eff} L_k L_l = l(l+1)\hbar^2 \quad . \tag{2.2.3}$$

This would give under the same simplifying assumptions

$$L^2 = l(l+1)\frac{\hbar^2}{K^2} \quad . \tag{2.2.4}$$

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 $m^{kl}_{eff} = Km^{kl}$ 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^{kl}_{eff}.

2.3 Dark Matter And Living Matter

In the sequel general ideas about the role of dark matter in condensed matter physics are described.

2.3.1 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" [K26]. 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 $v_0 \simeq 4.6 \times 10^{-4}$ 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. Proton mass ratio $m_p/m_e = 1836.15267261$ corresponds in good approximation to $n = 2^2 \times 3^3 \times 17 = 1836$. 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 $(\hbar_s/\hbar)^2 \simeq 4 \times 10^6$. 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 [K51]. 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 [K78] 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 [I74]. 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 [I99], and mitogenetic radiation became also known as bio-photons (the TGD based model for bio-photons is discussed in [K51]). 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 [I113] , 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 [K35] 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 [I131]. These biograms for which a general model is discussed in [K17] could be realized as dark photon laser beams.

In phantom DNA effect [I95] 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 [I89] 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 [K47]. This rule has been proposed on basis of experimental findings [I77] 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 [K47] 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 $f_0 = \beta f$.

2.3.2 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 [K35] 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} [K35]. 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 [K35], 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 [K35].

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

$$\oint (p - ZeA)dl = n\hbar \ , \tag{2.3.1}$$

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 [K80]. 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 [K28] 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 [K42].

2.4 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.

2.4.1 Massless Extremals

Massless extremals (MEs) are an extremely general solution set of field equations associated with Kähler action [K49] and representing various gauge – and gravitational fields [K68]. 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 [K68]. 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 [K71, K70].

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

$$s^k = f^k(k \cdot m, u) \ , \tag{2.4.1}$$

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

$$ds^2 = g_{S_+S_-} dS_+ dS_- + g_{11} dE_1^2 + g_{22} dE_2^2 \ .$$

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

$$S_+ + S_- = 2m^0 \quad .$$

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

$$\epsilon_i \to \hat{\epsilon}_i = \epsilon_i + k\nabla S_+ \quad ,$$

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

$$(\nabla S_+)^2 = (\nabla S_-)^2 = 0 \quad , \quad \nabla S_+ \cdot \nabla S_- \neq 0 \quad ,$$

$$\nabla S_+ \cdot \nabla E_i = 0 \quad , \qquad \frac{\nabla E_i \cdot \nabla S_-}{\nabla S_+ \cdot \nabla S_-} = k_i(S_+) \quad .$$

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.

2.4.2 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 [K35] 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.

2.4.3 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:

$$\begin{aligned} D_\beta F^{\alpha\beta} &= eJ^\alpha \ , \\ J^\alpha &= Jk^\alpha \ . \end{aligned} \tag{2.4.2}$$

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 $J \propto sin(k_z(t-z))$

$$\begin{aligned} a^\dagger(p) &\rightarrow a^\dagger(p) + g(p) \ , \\ g(p) &= \sum_n \delta(p^0, k_n^0) K(p, k_n) J(k_n^z, p_T) \ , \\ K(p,k) &= \epsilon(p) \cdot k \frac{1}{i(p_z - k_z)} (exp(ip_z L) - 1) \ , \\ k_n &= nk_0 = \frac{n2\pi}{L}(1,1,0,0) \ . \end{aligned} \tag{2.4.3}$$

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 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

$$g(p) \rightarrow \sum_n exp(i\phi_n) exp(ip_z z_n) exp(ip_T \cdot x_T) g_n(p) \ . \tag{2.4.4}$$

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.

2.4.4 Quantum Holography And Quantum Information Theory

Sokolov and collaborators [B28] 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 [B28] 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 [B28], is replaced with ME or set of parallel MEs. The neural window hypothesis [K81] 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 [B28] 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 [K42] 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 [K47] explains water memory and the effects of homeopathic remedies [I77] 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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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.

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   The concrete realization of holographic teleportation proposed in [B28] 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 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 [K42] 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 [I77], 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 [K96]. 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 [K42, K35, K82].

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

$$x + ey \to f(x + ey) \ ,$$

$$e^2 = 1 \ .$$

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.

2.4.5 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 [J12].

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 [K17]. 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 [I106]) 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 [K20]. 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 [J8].

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 [K66].

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 [J21, J9] 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

$$d \gg \frac{\omega}{ZeE} \ .$$

For $E \sim .1$ V/m and $\omega \sim GHz$ which are typical values used in experiments [J12], 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 $L_e(173) = \sqrt{5}L(173) \simeq 1.6 \times 10^{-5}$ 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 [J22] 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 [K42] 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 [A5]. I have proposed in [K71, K70] 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 [I106] 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 [I95] 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.

2.4.6 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 [I95] 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 [I137] 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 [I95]. 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 [K42]. 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 [I99] 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 [K112]. MEs would simply mimic the medicine. There are well documented effects related to the ability of water to absorb and transmit frequencies [J27]. 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 [E3]. 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.

2.5 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.

2.5.1 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 [J14] 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 [K92, K36] 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.

2.5.2 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.

2.5.3 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 [K35] 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 [J36] 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 [K35]. 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.

2.5.4 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) [K25] 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 [K25]. 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

$$\sum_{n \geq 0} b_n 2^n \to \sum_{m \geq 1} 2^{-m+1} \sum_{(k-1)m \leq n < km} b_n 2^n \quad .$$

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 [L2] 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).

n	89	107	113	127
f_e/Hz	2.7×10^{12}	1.0×10^7	1.6×10^5	10
n	151	157	163	167
T	19.4 d	3.40 y	218.0 y	3.49×10^3 y

(2.5.1)

2.6 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.

2.6.1 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 [I28]: Unidentified Infrared Bands (UIBs), Diffuse Interstellar Bands (DIBs) [I15], and Extended Red Emission (ERE) [I135] 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 [I28]. 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 2.1: 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 2.2: 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 2.1 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 [I28], 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 [I75] to model the observed UIBs. It is believed that PAHs are produced in reactions involving photosynthesis and are regarded as precedessors of biotic life [I22]. 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 [I28]. 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) [I28, I135] 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 [I135].

According to [I28] 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 $k \to k + 3$ 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.

2.6.2 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 [I101].

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 [I78].

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.

2.6.3 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 [I134] 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 [I134] 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 [I134] 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 [I134] 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 [I134]. 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

$$\Delta E_{k,n}(p) = E_0(k,p) \times (1 - 2^{-n}) \ ,$$
$$E_0(k,p) = E_0(137,p)2^{137-k} \simeq 2^{137-k} \times .5 \ \ eV \ \ .$$

$$\Delta E_{k,n}(e) = E_0(k,e) \times (1 - 2^{-n}) \ ,$$
$$E_0(k,e) = \frac{m_p}{2^{11}m_e} E_0(137,p)2^{148-k} \simeq 2^{148-k} \times .4 \ \ eV \ \ .$$

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

(2.6.1)

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 [I95, I89] 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 [I41]. 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 2.3: 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 2.4: 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 2.4** 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 [H1] ("Hessdalen phenomenon" is the term used).

1. The spectrum is a band in the interval 500-600 nm whereas the typical ERE [I135] 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 [I49, I50], which in turn is basic step in [I51] [I51], 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.

2.6.4 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 $\sim 5 \times 10^3$ 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 [I135]. 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 [K55], [F2] 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 $10^3 R_E$). 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 $d \sim 10^2 R_E$ 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" [K55].

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 [I89] 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 [**?**, K55]. 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.

2.7 Quantum Model For The Direct Currents Of Becker

Robert Becker [J8] 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.

2.7.1 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`) [J8], 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 [K80]). 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 [K3].

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 [J3] 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" [J3] 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 [J3] 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, microorganisms, 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 [K3] 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 [K44]), 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 [K75] [L22] for the findings of Pollack [L22] 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 [K93, K78].

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 [K47].

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 [K35, K74].

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 [K52].

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 [I67]: 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$\rightarrow$ ATP process occurring during electronic transport cycle in mitochondrial membrane. The connection with metabolism forces to ask how the formation of high energy phosphate bond in the addition of phosphate to ADP relates to the transfer of electrons to smaller space-time sheet. Somehow the energy of electrons must go to the formation of this bond: perhaps the dropping of electron back to larger space-time sheet transfers the energy to the high energy phosphate bond.

   In many-sheeted space-time particles topologically condense at all space-time sheets having projection to given region of space-time so that this option makes sense only near the boundaries of space-time sheet of a given system. Also p-adic phase transition increasing the

size of the space-time sheet could take place and the liberated energy would correspond to the reduction of zero point kinetic energy. Particles could be transferred from a portion of magnetic flux tube portion to another one with different value of magnetic field and possibly also of Planck constant h_{eff} so that cyclotron energy would be liberated.

3. The transfer of particles between space-time sheets with different p-adic length scales is not the only one that one can consider, and recently a more elegant mechanism has emerged [K52]. 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`) [I91] for the expectation that the healing effect of the acupuncture involves metabolism (see the popular article in Sciencedaily (see `http://tinyurl.com/3734uub`) [I69]).

   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.

2.7.2 Quantum Model For Effective Semiconductor Property

Becker [J8] 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

$$i\partial_t \Psi_k \quad = \quad (-\frac{\hbar^2}{2m_k}\partial_z^2 + q_k E z)\Psi_k \quad . \tag{2.7.1}$$

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

$$\sigma = E = \sum \sigma_i = \sum_i q_i \overline{\Psi}_i \Psi_i \ . \tag{2.7.2}$$

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

$$E_{tot} = E + E_0 \ . \tag{2.7.3}$$

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

$$j_k = \frac{i\hbar q_k}{2m_k} \overline{\Psi}_k \partial_z^{\leftrightarrow} \Psi_k \ . \tag{2.7.4}$$

In stationary situation the net current must vanish:

$$\sum_k j_k = 0 \ . \tag{2.7.5}$$

A stronger condition is that individual currents vanish at the plates:

$$j_k = 0 \ . \tag{2.7.6}$$

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).

$$\Psi = R(aexp(iU) + bexp(-iU))exp(-iE_n t) \tag{2.7.7}$$

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

$$\begin{aligned} z &\rightarrow \frac{(z-z_0)}{z_1} \equiv x \ , \\ z_0 &= \frac{E_n}{qE} \ , \ z_1 = (\frac{\hbar^2}{2mqE})^{1/3} \ . \end{aligned} \tag{2.7.8}$$

to

$$(\partial_x^2 + x)\Psi = 0 \ . \tag{2.7.9}$$

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

$$\begin{aligned} \left[(\partial_x^2 - U_x^2 + x)R\right] cos(U) &+ \left[U_{xx} + 2\partial_x R \partial_x U\right] sin(U) = 0 \ , \\ \left[(\partial_x^2 - U_x^2 + x)R\right] sin(U) &- \left[U_{xx} - 2\partial_x R \partial_x U\right] cos(U) = 0 \ . \end{aligned} \tag{2.7.10}$$

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

$$j = \frac{\hbar}{2m}\frac{U_x}{z_1}R^2 \ , \ z_1 = (\frac{\hbar}{2mqE})^{1/3} \ . \tag{2.7.11}$$

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

$$\Psi = R_0 exp\left(\frac{i}{\hbar}\int_0^z \sqrt{2m}\sqrt{E - qEz}dz\right) = R_0 exp\left(i\int_0^x x^{1/2}dx\right) \ . \tag{2.7.12}$$

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

$$\frac{\oint p_z dz}{\hbar} = \frac{2}{\hbar}\int_0^h p_z dz = n \ . \tag{2.7.13}$$

This gives

$$\frac{\oint p_z dz}{\hbar} = \frac{2\sqrt{2m}}{\hbar}\int_0^h \sqrt{E_n - qEz}dz = 2\int_0^{x_0} x^{1/2} = \frac{4}{3}x_0^{3/2} = n \ . \tag{2.7.14}$$

Note that the turning point for classical orbit corresponds to $z_{max} = E_n/qE$.

2. One obtains

$$E_n = \frac{1}{2}(\frac{nqE\hbar^2}{r\sqrt{m}})^{2/3} \ , \ r = \int_0^1 (1-u)^{1/2}du = \frac{2}{3} \ . \tag{2.7.15}$$

The value of z_{max} is

$$z_{max} = \frac{E_n}{qE} = \frac{n^{2/3}}{2r^{2/3}}(\frac{\hbar^2}{qEm})^{1/3} \ . \tag{2.7.16}$$

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 [K80] 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

$$\frac{x(Ca^{++})}{x(Na^+)} = (\frac{r(Ca^{++})}{r(Na^+)})^2 \times \frac{23}{2 \times 40} \quad . \tag{2.7.17}$$

   $r^2(Ca_{++}) \sim 2r^2(Na_+)$ 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 [L2].

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 [I100] (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 [J37]. 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 [J37]. 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 [K114]. 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 [I134]. 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 [K114] 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 [K3].

The place coding by phase shifts was discovered by O'Reefe and Recce [J35]. In [J42, J41]. 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 [J42]. 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.

2.7.3 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 [L14]), 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 [K114] 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 [K47]. 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 [K98]).

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 [K114] 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 [L17]. 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`) [L18] 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`) [L15] 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.

2.8 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.

2.8.1 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 [K27].

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 [K92]. 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.

2.8.2 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 [K36, K34]. 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 [C3] 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 [K36, K34] inspired by RHIC findings [C6] 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 [C6]. 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 [C1]. 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.

2.8.3 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:

$$\begin{aligned} \gamma &= 3J - \frac{1}{2} sin^2\theta_W Z^0 \ , \\ Z^0 &= 2J + 4e^0 \wedge e^3 \ , \\ J &= 2(e^0 \wedge e^3 + e^1 \wedge e^2) \ . \end{aligned} \tag{2.8.1}$$

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 3

Topological Quantum Computation in TGD Universe

3.1 Introduction

Quantum computation is perhaps one of the most rapidly evolving branches of theoretical physics. TGD inspired theory of consciousness has led to new insights about quantum computation and in this chapter I want to discuss these ideas in a more organized way.

There are three mathematically equivalent approaches to quantum computation [B5] : quantum Turing machines, quantum circuits, and topological quantum computation (TQC). In fact, the realization that TGD Universe seems to be ideal place to perform TQC [B24]. [C4] served as the stimulus for writing this chapter.

Quite generally, quantum computation allows to solve problems which are NP hard, that is the time required to solve the problem increases exponentially with the number of variables using classical computer but only polynomially using quantum computer. The topological realization of the computer program using so called braids resulting when threads are weaved to 2-dimensional patterns is very robust so that de-coherence, which is the basic nuisance of quantum computation, ceases to be a problem. More precisely, the error probability is proportional to $exp(-\alpha l)$, where l is the length scale characterizing the distance between strands of the braid [B24].

3.1.1 Evolution Of Basic Ideas Of Quantum Computation

The notion of quantum computation goes back to Feynman [B47] who demonstrated that some computational tasks boil down to problems of solving quantum evolution of some physical system, say electrons scattering from each other. Many of these computations are NP hard, which means that the number of computational steps required grows exponentially with the number of variables involved so that they become quickly unsolvable using ordinary computers. A quicker way to do the computation is to make a physical experiment. A further bonus is that if you can solve one NP hard problem, you can solve many equivalent NP hard problems. What is new that quantum computation is not deterministic so that computation must be carried out several times and probability distribution for the outcomes allows to deduce the answer. Often however the situation is such that it is easy to check whether the outcome provides the sought for solution.

Years later David Deutch [B13] transformed Feynman's ideas into a detailed theory of quantum computation demonstrating how to encode quantum computation in a quantum system and researchers started to develop applications. One of the key factors in the computer security is cryptography which relies on the fact that the factorization of large integers to primes is a NP hard problem. Peter Shor [B46] discovered an algorithm, which allows to carry out the factorization in time, which is exponentially shorter than by using ordinary computers. A second example is problem of searching a particular from a set of N items, which requires time proportional to N classically but quantally only a time proportional to $\sqrt{N}$.

The key notion is quantum entanglement which allows to store information in the relationship between systems, qubits in the simplest situation. This means that information storage

capacity increases exponentially as a function of number of qubits rather than only linearly. This explains why NP hard problems which require time increasing exponentially with the number of variables can be solved using quantum computers. It also means exponentially larger information storage capacity than possible classically.

Recall that there are three equivalent approaches to quantum computation: quantum Turing machine, quantum circuits, and topology based unitary modular functor approach. In quantum circuit approach the unitary time evolution defining the quantum computation is assumed to be decomposable to a product of more elementary operations defined by unitary operators associated with quantum gates. The number of different gates needed is surprisingly small: only 1-gates generating unitary transformations of single qubit, and a 2-gate representing a transformation which together with 1-gates is able to generate entanglement are needed to generate a dense subgroup of unitary group $U(2^n)$ in the case of n-qubit system. 2-gate could be conditional NOT (CNOT). The first 1-gate can induce a phase factor to the qubit 0 and do nothing for qubit 1. Second 1-gate could form orthogonal square roots of bits 1 and 0 as superposition of 1 and 0 with identical probabilities.

The formal definition of the quantum computation using quantum circuit is as a computation of the value of a Boolean function of n Boolean arguments, for instance the k:th bit of the largest prime factor of a given integer. The unitary operator U is constructed as a product of operators associated with the basic gates. It is said that the function coding the problem belongs to the class BQP (function is computable with a bounded error in polynomial time) if there exists a classical polynomial-time (in string length) algorithm for specifying the quantum circuit. The first qubit of the outgoing n-qubit is measured and the probability that the value is 0 determines the value of the bit to be calculated. For instance, for $p(0) \geq 2/3$ the bit is 0 and for $p(0) \geq 1/3$ the bit is 1. The evaluation of the outcome is probabilistic and requires a repeat the computation sufficiently many times.

The basic problem of quantum computation is the extremely fragility of the physical qubit (say spin). The fragility can be avoided by mapping q-bits to logical qubits realized as highly entangled states of many qubits and quantum error-correcting codes and fault tolerant methods [B35, B45, B14] rely on this.

The space W of the logical qubits is known as a code space. The sub-space W of physical states of space $Y = V \otimes V..... \otimes V$ is called k-code if the effect of any k-local operator (affecting only k tensor factors of Y linearly but leaving the remaining factors invariant) followed by an orthogonal projection to W is multiplication by scalar. This means that k-local operator modify the states only in directions orthogonal to W.

These spaces indeed exist and it can be shown that the quantum information coded in W is not affected by the errors operating in fewer than $k/2$ of the n particles. Note that $k = 3$ is enough to guarantee stability with respect to 1-local errors. In this way it is possible to correct the errors by repeated quantum measurements and by a suitable choice of the sub-space eliminate the errors due to the local changes of qubits by just performing a projection of the state back to the subspace (quantum measurement).

If the error magnitude is below so called accuracy threshold, arbitrary long quantum computations are reliable. The estimates for this constant vary between 10^{-5} and 10^{-3}. This is beyond current technologies. Error correction is based on the representation of qubit as a logical qubit defined as a state in a linear sub-space of the tensor product of several qubits.

Topological quantum computation [B24] provides an alternative approach to minimize the errors caused by de-coherence. Conceptually the modular functor approach [B24, B29] is considerably more abstract than quantum circuit approach. Unitary modular functor is the S-matrix of a topological quantum field theory. It defines a unitary evolution realizing the quantum computation in macroscopic topological ground states degrees of freedom. The nice feature of this approach is that the notion of physical qubit becomes redundant and the code space defined by the logical qubits can be represented in terms topological and thus non-local degrees of freedom which are stable against local perturbations as required.

3.1.2 Quantum Computation And TGD

Concerning quantum computation [B5] in general, TGD TGD inspired theory of consciousness provides several new insights.

Quantum jump as elementary particle of consciousness and cognition

Quantum jump is interpreted as a fundamental cognitive process leading from creative confusion via analysis to an experience of understanding, and involves TGD counterpart of the unitary process followed by state function reduction and state preparation. One can say that quantum jump is the elementary particle of consciousness and that selves consists of sequences of quantum jump just like hadrons, nuclei, atoms, molecules,... consist basically of elementary particles. Self loses its consciousness when it generates bound state entanglement with environment. The conscious experience of self is in a well-defined sense a statistical average over the quantum jump during which self exists. During macro-temporal quantum coherence during macro-temporal quantum coherence a sequence of quantum jumps integrates effectively to a single moment of consciousness and effectively defines single unitary time evolution followed by state function reduction and preparation. This means a fractal hierarchy of consciousness very closely related to the corresponding hierarchy for bound states of elementary particles and structure formed from them.

Negentropy Maximization Principle guarantees maximal entanglement

Negentropy Maximization Principle is the basic dynamical principle constraining what happens in state reduction and self measurement steps of state preparation. Each self measurement involves a decomposition of system into two parts. The decomposition is dictated by the requirement that the reduction of entanglement entropy in self measurement is maximal. Self measurement can lead to either unentangled state or to entangled state with density matrix which is proportional to unit matrix (density matrix is the observable measured). In the latter case maximally entangled state typically involved with quantum computers results as an outcome. Hence Nature itself would favor maximally entangling 2-gates. Note however that self measurement occurs only if it increases the entanglement negentropy.

Number theoretical information measures and extended rational entanglement as bound state entanglement

The emerging number theoretical notion of information allows to interpret the entanglement for which entanglement probabilities are rational (or belong to an extension of rational numbers defining a finite extension of p-adic numbers) as bound state entanglement with positive information content. Macro-temporal quantum coherence corresponds to a formation of bound entanglement stable against state function reduction and preparation processes.

Spin glass degeneracy, which is the basic characteristic of the variational principle defining space-time dynamics, implies a huge number of vacuum degrees of freedom, and is the key mechanism behind macro-temporal quantum coherence. Spin glass degrees of freedom are also ideal candidates qubit degrees of freedom. As a matter fact, p-adic length scale hierarchy suggests that qubit represents only the lowest level in the hierarchy of qupits defining p-dimensional state spaces, p prime.

Time mirror mechanism and negative energies

The new view about time, in particular the possibility of communications with and control of geometric past, suggests the possibility of circumventing the restrictions posed by time for quantum computation. Iteration based on initiation of quantum computation again and again in geometric past would make possible practically instantaneous information processing.

Space-time sheets with negative time orientation carry negative energies. Also the possibility of phase conjugation of fermions is strongly suggestive. It is also possible that anti-fermions possess negative energies in phases corresponding to macroscopic length scales. This would explain matter-antimatter asymmetry in elegant way. Zero energy states would be ideal for quantum computation purposes and could be even created intentionally by first generating a p-adic surface representing the state and then transforming it to a real surface.

The most predictive and elegant cosmology assumes that the net quantum numbers of the Universe vanish so that quantum jumps would occur between different kinds of vacua. Crossing symmetry makes this option almost consistent with the idea about objective reality with definite conserved total quantum numbers but requires that quantum states of 3-dimensional quantum

theory represent S-matrices of 2-dimensional quantum field theory. These quantum states are thus about something. The boundaries of space-time surface are most naturally light-like 3-surfaces space-time surface and are limiting cases of space-like 3-surface and time evolution of 2-surface. Hence they would act naturally as space-time correlates for the reflective level of consciousness.

3.1.3 TGD And The New Physics Associated With TQC

TGD predicts the new physics making possible to realized braids as entangled flux tubes and also provides a detailed model explaing basic facts about anyons.

Topologically quantized magnetic flux tube structures as braids

Quantum classical correspondence suggests that the absolute minimization of Kähler action, which might make sense for Eucdliain regions, could correspond to a space-time representation of second law and that the 4-surfaces approach asymptotically space-time representations of systems which do not dissipate anymore. The correlate for the absence of dissipation is the vanishing of Lorentz 4-force associated with the induced Kähler field. This condition can be regarded as a generalization of Beltrami condition for magnetic fields and leads to very explicit general solutions of field equations [K15].

The outcome is a general classification of solutions based on the dimension of CP_2 projection. The most unstable phase corresponds to $D = 2$-dimensional projection and is analogous to a ferromagnetic phase. $D = 4$ projection corresponds to chaotic de-magnetized phase and $D = 3$ is the extremely complex but ordered phase at the boundary between chaos and order. This phase was identified as the phase responsible for the main characteristics of living systems [K71, K70]. It is also ideal for quantum computations since magnetic field lines form extremely complex linked and knotted structures.

The flux tube structures representing topologically quantized fields, which have $D = 3$ -dimensional CP_2 projection, are knotted, linked and braided, and carry an infinite number of conserved topological charges labelled by representations of color group. They seem to be tailor-made for defining the braid structure needed by TQC. The boundaries of the magnetic flux tubes correspond to light-like 3-surfaces with respect to the induced metric (being thus metrically 2-dimensional and allowing conformal invariance) and can be interpreted either as 3-surfaces or time-evolutions of 2-dimensional systems so that S-matrix of 2-D system can be coded into the quantum state of conformally invariant 3-D system.

Anyons in TGD

TGD suggests a many-sheeted model for anyons used in the modelling of quantum Hall effect [D16, D10, D13]. Quantum-classical correspondence requires that dissipation has space-time correlates. Hence a periodic motion should create a permanent track in space-time. This kind of track would be naturally magnetic flux tube like structure surrounding the Bohr orbit of the charged particle in the magnetic field. Anyon would be electron plus its track.

The magnetic field inside magnetic flux tubes impels the anyons to the surface of the magnetic flux tube and a highly conductive state results. The partial fusion of the flux tubes along their boundaries makes possible de-localization of valence anyons localized at the boundaries of flux tubes and implies a dramatic increase of longitudinal conductivity. When magnetic field is gradually increased the radii of flux tubes and the increase of the net flux brings in new flux tubes. The competition of these effects leads to the emergence of quantum Hall plateaus and sudden increase of the longitudinal conductivity σ_{xx}.

The simplest model explains only the filling fractions $\nu = 1/m$, m odd. The filling fractions $\nu = N/m$, m odd, require a more complex model. The transition to chaos means that periodic orbits become gradually more and more non-periodic: closed orbits fail to close after the first turn and do so only after N 2π rotations. Tracks would become N-branched surfaces. In N-branched space-time the single-valued analytic two particle wave functions $(\xi_k - \xi_l)^m$ of Laughlin [D13] correspond to multiple valued wave functions $(z_k - z_l)^{m/N}$ at its M^4_+ projection and give rise to a filling fraction $\nu = N/m$. The filling fraction $\nu = N/m$, m even, requires composite fermions [D17]. Anyon tracks can indeed contain up to $2N$ electrons if both directions of spin are allowed so that

a rich spectroscopy is predicted: in particular anyonic super-conductivity becomes possible by 2-fermion composites. The branching gives rise to Z_N-valued topological charge.

One might think that fractional charges could be only apparent and result from the multi-branched character as charges associated with a single branch. This does not seem to be the case. Rather, the fractional charges result from the additional contribution of the vacuum Kähler charge of the anyonic flux tube to the charge of anyon. For $D = 3$ Kähler charge is topologized in the sense that the charge density is proportional to the Chern-Simons term. Also anyon spin could become genuinely fractional due to the vacuum contribution of the Kähler field to the spin. Besides electronic anyons also anyons associated with various ions are predicted and certain strange experimental findings about fractional Larmor frequencies of proton in water environment [D14] , [J40] have an elegant explanation in terms of protonic anyons with $\nu = 3/5$. In this case however the magnetic field was weaker than the Earth's magnetic field so that the belief that anyons are possible only in systems carrying very strong magnetic fields would be wrong.

In TGD framework anyons as punctures of plane would be replaced by wormhole like tubes connecting different points of the boundary of the magnetic flux tube and are predicted to always appear as pairs as they indeed do. Detailed arguments demonstrate that TGD anyons are for $N = 4$ ($\nu = 4/m$) ideal for realizing the scenario of [B24] for TQC.

The TGD inspired model of non-Abelian anyons is consistent with the model of anyons based on spontaneous symmetry breaking of a gauge symmetry G to a discrete sub-group H dynamically [A26]. The breaking of electro-weak gauge symmetry for classical electro-weak gauge fields occurs at the space-time sheets associated with the magnetic flux tubes defining the strands of braid. Symmetry breaking implies that elements of holonomy group span H. This group is also a discrete subgroup of color group acting as isotropy group of the many-branched surface describing anyon track inside the magnetic flux tube. Thus the elements of the holonomy group are mapped to a elements of discrete subgroup of the isometry group leading from branch to another one but leaving many-branched surface invariant.

Witten-Chern-Simons action and light-like 3-surfaces

The magnetic field inside magnetic flux tube expels anyons at the boundary of the flux tube. In quantum TGD framework light-like 3-surfaces of space-time surface and future light cone are in key role since they define causal determinants for Kähler action. They also provide a universal way to satisfy boundary conditions. Hence also the boundaries of magnetic flux tube structures could be light like surfaces with respect to the induced metric of space-time sheet and would be somewhat like black hole horizons. By their metric 2-dimensionality they allow conformal invariance and due the vanishing of the metric determinant the only coordinate invariant action is Chern-Simons action associated Kähler gauge potential or with the induced electro-weak gauge potentials.

The quantum states associated with the light-like boundaries would be naturally "self-reflective" states in the sense that they correspond to S-matrix elements of the Witten-Chern-Simons topological field theory. Modular functors could results as restriction of the S-matrix to ground state degrees of freedom and Chern-Simons topological quantum field theory is a promising candidate for defining the modular functors [A12, A23].

Braid group B_n is isomorphic to the first homotopy group of the configuration space $C_n(R^2)$ of n particles. $C_n(R^2)$ is $((R^2)_n - D)/S_n$, where D is the singularity represented by the configurations in which the positions of 2 or more particles. and be regarded also as the configuration associated with plane with $n + 1$ punctures with $n + 1$:th particle regarded as inert. The infinite order of the braid group is solely due to the 2-dimensionality. Hence the dimension $D = 4$ for space-time is unique also in the sense that it makes possible TQC.

3.1.4 TGD And TQC

Many-sheeted space-time concept, the possibility of negative energies, and Negentropy Maximization Principle inspire rather concrete ideas about TQC. NMP gives good hopes that the laws of Nature could take care of building fine-tuned entanglement generating 2-gates whereas 1-gates could be reduced to 2-gates for logical qubits realized using physical qubits realized as Z^4 charges and not existing as free qubits.

Only 2-gates are needed

The entanglement of qubits is algebraic which corresponds in TGD Universe to bound state entanglement. Negentropy Maximization Principle implies that maximal entanglement results automatically in quantum jump. This might saves from the fine-tuning of the 2-gates. In particular, the maximally entangling Yang-Baxter R-matrix is consistent with NMP.

TGD suggests a rather detailed physical realization of the model of [B24] for anyonic quantum computation. The findings about strong correlation between quantum entanglement and topological entanglement are apparently contradicted by the Temperley-Lie representations for braid groups using only single qubit. The resolution of the paradox is based on the observation that in TGD framework batches containing anyon Cooper pair (AA) and single anyon (instead of two anyons as in the model of [B24]) allow to represent single qubit as a logical qubit, and that mixing gate and phase gate can be represented as swap operations s_1 and s_2. Hence also 1-gates are induced by the purely topological 2-gate action, and since NMP maximizes quantum entanglement, Nature itself would take care of the fine-tuning also in this case. The quantum group representation based on $q = exp(i2\pi/5)$ is the simplest representation satisfying various constraints and is also physically very attractive. [B24, B29].

TGD makes possible zero energy TQC

TGD allows also negative energies: besides phase conjugate photons also phase conjugate fermions and anti-fermions are possible, and matter-antimatter asymmetry might be only apparent and due to the ground state for which fermion energies are positive and anti-fermion energies negative.

This would make in principle possible zero energy topological quantum computations. The least one could hope wold be the performance of TQC in doubles of positive and negative energy computations making possible error detection by comparison. The TGD based model for anyon computation however leads to expect that negative energies play much more important role.

The idea is that the quantum states of light-like 3-surfaces represent 2-dimensional time evolutions (in particular modular functors) and that braid operations correspond to zero energy states with initial state represented by positive energy anyons and final state represented by negative energy anyons. The simplest way to realize braid operations is by putting positive *resp.* negative energy anyons near the boundary of tube T_1 *resp.* T_2. Opposite topological charges are at the ends of the magnetic threads connecting the positive energy anyons at T_1 with the negative energy anyons at T_2. The braiding for the threads would code the quantum gates physically.

Before continuing a humble confession is in order: I am not a professional in the area of quantum information science. Despite this, my hope is that the speculations below might serve as an inspiration for real professionals in the field and help them to realize that TGD Universe provides an ideal arena for quantum information processing, and that the new view about time, space-time, and information suggests a generalization of the existing paradigm to a much more powerful one.

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` [L19].

3.2 Existing View About Topological Quantum Computation

In the sequel the evolution of ideas related to topological quantum computation, dance metaphor, and the idea about realizing the computation using a system exhibiting so called non-Abelian Quantum Hall effect, are discussed.

3.2.1 Evolution Of Ideas About TQC

The history of the TQC paradigm is as old as that of QC and involves the contribution of several Fields Medalists. At 1987 to-be Fields Medalist Vaughan Jones [A30] demonstrated that the von Neumann algebras encountered in quantum theory are related to the theory of knots and allow

to distinguish between very complex knots. Vaughan also demonstrated that a given knot can be characterized in terms an array of bits. The knot is oriented by assigning an arrow to each of its points and projected to a plane. The bit sequence is determined by a sequence of bits defined by the self-intersections of the knot's projection to plane. The value of the bit in a given intersection changes when the orientation of either line changes or when the line on top of another is moved under it. Since the logic operations performed by the gates of computer can be coded to matrices consisting of 0s and 1s, this means that tying a know can encode the logic operations necessary for computation.

String theorist Edward Witten [A12], also a Fields Medalist, connected the work of Jones to quantum physics by showing that performing measurements to a system described by a 3-dimensional topological quantum field theory defined by non-Abelian Chern-Simons action is equivalent with performing the computation that a particular braid encodes. The braids are determined by linked word lines of the particles of the topological quantum field theory. What makes braids and quantum computation so special is that the coding of the braiding pattern to a bit sequence gives rise to a code, which corresponds to a code solving NP hard problem using classical computer.

1989 computer scientist Alexei Kitaev [B8] demonstrated that Witten's topological quantum field theory could form a basis for a computer. Then Fields Medalist Michael Freedman entered the scene and in collaboration with Kitaev, Michael Larson and Zhenghan Wang developed a vision of how to build a topological quantum computer [B24, B29] using system exhibiting so called non-Abelian quantum Hall effect [D11].

The key notion is Z_4 valued topological charge which has values 1 and 3 for anyons and 0 and 2 for their Cooper pairs. For a system of $2n$ non-Abelian anyon pairs created from vacuum there are n-1 anyon qubits analogous to spin. The notion of physical qubit is not needed at all and logical qubit is coded to the topological charge of the anyon Cooper pair. The basic idea is to utilize entanglement between Z_4 valued topological charges to achieve quantum information storage stable against de-coherence. The swap of neighboring strands of the braid is the topological correlate of a 2-gate which as such does not generate entanglement but can give rise to a transformation such as CNOT. When combined with 1-gates taking square root of qubit and relative phase, this 2-gate is able to generate $U(2^n)$.

The swap can be represented as the so called braid Yang-Baxter R-matrix characterizing also the deviation of quantum groups from ordinary groups [B37]. Quite generally, all unitary Yang-Baxter R-matrices are entangling when combined with square root gate except for special values of parameters characterizing them and thus there is a rich repertoire of topologically realized quantum gates. Temperley-Lieb representation provides a 1-qubit representation for swaps in 3-braid system [B37, B29]. The measurement of qubit reduces to the measurement of the topological charge of the anyon Cooper pair: in the case that it vanishes (qubit 0) the anyon Cooper pair can annihilate and this serves as the physical signature.

3.2.2 Topological Quantum Computation As Quantum Dance

Although topological quantum computation involves very abstract and technical mathematical thinking, it is possible to illustrate how it occurs by a very elegant metaphor. With tongue in cheek one could say that topological quantum computation occurs like a dance. Dancers form couples and in this dancing floor the partners can be also of same sex. Dancers can change their partners. If the partners are of the same sex, they define bit 1 and if they are of opposite sex they define bit 0.

To simplify things one can arrange dancers into a row or several rows such that neighboring partners along the row form a couple. The simplest situation corresponds to a single row of dancers able to make twists of 180 degrees permuting the dancers and able to change the partner to a new one any time. Dance corresponds to a pattern of tracks of dancers at the floor. This pattern can be lifted to a three-dimensional pattern introducing time as a third dimension. When one looks the tracks of a row of dancers in this 2+1-dimensional space-time, one finds that the tracks of the dancers form a complex weaved pattern known as braiding. The braid codes for the computation. The braiding consists of primitive swap operations in which two neighboring word lines twist around each other.

The values of the bits giving the result of the final state of the calculation can be detected since there is something very special which partners with opposite sex can do and do it sooner or

later. Just by looking which pairs do it allows to deduce the values of the bits. The alert reader has of course guessed already now that the physical characterization for the sex is as a Z^4 valued topological charge, which is of opposite sign for the different sexes forming Cooper pairs, and that the thing that partners of opposite sex can do is to annihilate! All that is needed to look for those pairs which annihilate after the dance evening to detect the 0s in the row of bits. The coding of the sex to the sign of the topological charge implies also robustness.

It is however essential that the value of topological charge for a given particle in the final state is not completely definite (this is completely general feature of all quantum computations). One can tell only with certain probability that given couple in the final state is male-female or male-male or female-female and the probabilities in question code for the braid pattern in turn coding for quantum logic circuit. Hence one must consider an ensemble of braid calculations to deduce these probabilities.

The basic computational operation permuting the neighboring topological charges is topological so that the program represented by the braiding pattern is very stable against perturbations. The values of the topological charges are also stable. Hence the topological quantum computation is a very robust process and immune to quantum de-coherence even in the standard physics context.

3.2.3 Braids And Gates

In order to understand better how braids define gates one must introduce some mathematical notions related to the braids.

Braid groups

Artin introduced the braid groups bearing his name as groups generated by the elements, which correspond to the cross section between neighboring strands of the braid. The definition of these groups is discussed in detail in [B37]. For a braid having $n+1$ strands the Artin group B_{n1} has n generators s_i. The generators satisfy certain relations. Depending on whether the line coming from left is above the line coming from right one has s_i or s_i^{-1}. The elements s_i and s_j commute for $i < j$ and $i > j+1$: $s_i s_j = s_j s_i$, which only says that two swaps which do not have common lines commute. For $i = j$ and $i = j+1$ commutativity is not assumed and this correspond to the situation in which the swaps act on common lines.

As already mentioned, Artin's braid group B_n is isomorphic with the homotopy group $\pi_1((R^2)^n/S_{n+1})$ of plane with $n+1$ punctures. B_n is infinite-dimensional because the conditions $s_i^2 = 1$ added to the defining relations in the case of permutation group S_n are not included. The infinite-dimensionality of homotopy groups reflects the very special topological role of 2-dimensional spaces.

One must consider also variants of braid groups encountered when all particles in question are not identical particles. The reason is that braid operation must be replaced by a 2π rotation of particle A around B when the particles are not identical.

1. Consider first the situation in which all particles are non-identical. The first homotopy group of $R^2)^n - D$, where D represents points configurations for which two or more points are identical is identical with the colored braid group B_n^c defined by $n+1$ punctures in plane such that $n+1$: th is passive (punctures are usually imagined to be located on line). Since particles are not identical the braid operation must be replaced by monodromy in which i: th particle makes 2π rotation around j: th particle. This group has generators

$$\gamma_{ij} = s_i ... s_{j-2} s_{j-1}^2 s_{j-2} ... s_i^{-1} \quad , i < j \quad , \tag{3.2.1}$$

   and can be regarded as a subgroup of the braid group.

2. When several representatives of a given particle species are present the so called partially colored braid group B_n^{pc} is believed to describe the situation. For pairs of identical particles the generators are braid generators and for non-identical particles monodromies appear as

generators. It will be found later that in case of anyon bound states, the ordinary braid group with the assumption that braid operation can lead to a temporary decay and recombination of anyons to a bound state, might be a more appropriate model for what happens in braiding.

3. When all particles are identical, one has the braid group B_n, which corresponds to the fundamental group of $C_n(R^2) = ((R^2)^n - D)/S_n$. Division by S_n expresses the identicality of particles.

Extended Artin's group

Artin's group can be extended by introducing any group G and forming its tensor power $G^{\otimes^n} = G \otimes ... \otimes G$ by assigning to every strand of the braid group G. The extended group is formed from elements of $g_1 \otimes g_2 .... \otimes g_n$ and s_i by posing additional relations $g_i s_j = s_j g_i$ for $i < j$ and $i > j + 1$. The interpretation of these relations is completely analogous to the corresponding one for the Artin's group.

If G allows representation in some space V one can look for the representations of the extended Artin's group in the space $V^{\otimes^n}$. In particular, unitary representations are possible. The space in question can also represent physical states of for instance anyonic system and the element g_i associated with the lines of the braid can represent the unitary operators characterizing the time development of the strand between up to the moment when it experiences a swap operation represented by s_i after this operation g_i becomes $s_i g_i s_i^{-1}$.

Braids, Yang-Baxter relations, and quantum groups

Artin's braid groups can be related directly to the so called quantum groups and Yang-Baxter relations. Yang-Baxter relations follow from the relation $s_1 s_2 s_1 = s_2 s_1 s_2$ by noticing that these operations permute the lines 123 of the braid to the order 321. By assigning to a swap operation permuting i:th and j:th line group element R_{ij} when i:th line goes over the j:th line, and noticing that $R_{ij} i$ acts in the tensor product $V_i \otimes V_j$, one can write the relation for braids in a form

$$R_{32} R_{13} R_{12} = R_{12} R_{13} R_{23} \quad .$$

Braid Yang-Baxter relations are equivalent with the so called algebraic Yang-Baxter relations encountered in quantum group theory. Algebraic R can be written as $R_a = RS$, where S is the matrix representing swap operation as a mere permutation. For a suitable choice R_a provides the fundamental representations for the elements of the quantum group $SL(n)_q$ when V is n-dimensional.

The equations represent n^6 equations for n^4 unknowns and are highly over-determined so that solving the equations is a difficult challenge. Equations have symmetries which are obvious on basis of the topological interpretation. Scaling and automorphism induced by linear transformations of V act as symmetries, and the exchange of tensor factors in $V \otimes V$ and transposition are symmetries as also shift of all indices by a constant amount (using modulo N arithmetics).

Unitary R-matrices

Quite a lot is known about the general solutions of the Yang-Baxter equations and for $n = 2$ the general unitary solutions of equations is known [B33]. All of these solutions are entangling and define thus universal 1-gates except for certain parameter values.

The first solution is

$$R = \frac{1}{\sqrt{2}} \begin{pmatrix} 1 & \cdot & \cdot & 1 \\ \cdot & 1 & -1 & \cdot \\ \cdot & 1 & 1 & \cdot \\ -1 & \cdot & \cdot & 1 \end{pmatrix} \tag{3.2.2}$$

and contains no free parameters (dots denote zeros). This R-matrix is strongly entangling. Note that the condition $R^8 = 1$ is satisfied. The defining relations for Artin's braid group allow also

more general solutions obtained by multiplying R with an arbitrary phase factor. This would mean that $R^8 = 1$ constraint is not satisfied anymore. One can argue that over-all phase does not matter: on the other hand, the over all phase is visible in knot invariants defined by the trace of R.

The second and third solution come as families labelled four phases a, b, c and d:

$$R'(a,b,c,d) = \frac{1}{\sqrt{2}} \begin{pmatrix} a & \cdot & \cdot & \cdot \\ \cdot & & b & \cdot \\ \cdot & c & \cdot & \cdot \\ \cdot & \cdot & \cdot & d \end{pmatrix}$$

$$R''(a,b,c,d) = \frac{1}{\sqrt{2}} \begin{pmatrix} \cdot & \cdot & \cdot & a \\ \cdot & b & \cdot & \cdot \\ \cdot & \cdot & c & \cdot \\ d & \cdot & \cdot & \cdot \end{pmatrix} \tag{3.2.3}$$

These matrices are not as such entangling. The products $U_1 \otimes U_2 R V_1 \otimes V_2$, where U_i and V_i are 2×2 unitary matrices, are however entangling matrices and thus act as universal gates for $ad - bc \neq 0$ guaranteeing that the state $a|11\rangle + b|10\rangle + |01\rangle + |00\rangle$ is entangled.

It deserves to be noticed that the swap matrix

$$S = R'(1,1,1,1) = \frac{1}{\sqrt{2}} \begin{pmatrix} 1 & \cdot & \cdot & \cdot \\ \cdot & & 1 & \cdot \\ \cdot & 1 & 1 & \cdot \\ \cdot & \cdot & \cdot & 1 \end{pmatrix} \tag{3.2.4}$$

permuting the qubits does not define universal gate. This is understandable since in this representation of braid group reduces it to permutation group and situation becomes completely classical.

One can write all solutions R of braid Yang-Baxter equation in the form $R = R_a$, where R_a is the solution of so called algebraic Yang-Baxter equation. The interpretation is that the swap matrix S represents the completely classical part of the swap operation since it acts as a mere permutation whereas R_a represents genuine quantum effects related to the swap operation.

In the article of Kauffman [B37] its is demonstrated explicitly how to construct CNOT gate as a product MRN, where M and N are products of single particle gates. This article contains also a beautiful discussion about how the traces of the unitary matrices defined by the braids define knot invariants. For instance, the matrix R satisfies $R^8 = 1$ so that the invariants constructed using R as 2-gate cannot distinguish between knots containing n and $n + 8k$ sub-sequent swaps. Note however that the multiplication of R with a phase factor allows to get rid of the 8-periodicity.

Knots, links, braids, and quantum 2-gates

In [B37] basic facts about knots, links, and their relation to braids are discussed. Knot diagrams are introduced, the so called Reidermeister moves and homeomorphisms of plane as isotopies of knots and links are discussed. Also the notion of braid closure producing knots or links is introduced together with the theorem of Markov stating that any knot and link corresponds to some (not unique) braid. Markov moves as braid deformations leaving corresponding knots and links invariant are discussed and it the immediate implication is that traces of the braid matrices define knot invariants. In particular, the traces of the unitary matrices defined by R-matrix define invariants having same value for the knots and links resulting in the braid closure.

In [B37] the state preparation and quantum measurement allowing to deduce the absolute value of the trace of the unitary matrix associated with the braid defining the quantum computer is discussed as an example how quantum computations could occur in practice. The braid in question is product of the braid defining the invariant and trivial braid with same number n of strands. The incoming state is maximally entangled state formed $\sum_n |n\rangle \otimes |n\rangle$, where n runs over all possible bit

sequences defined by the tensor product of n qubits. Quantum measurement performs a projection to this state and from the measurements it is possible to deduce the absolute value of the trace defining the knot invariant.

3.2.4 About Quantum Hall Effect And Theories Of Quantum Hall Effect

Using the dance metaphor for TQC, the system must be such that it is possible to distinguish between the different sexes of dancers. The proposal of [B24] is that the system exhibiting so called non-Abelian Quantum Hall effect [D10, D12] could make possible realization of the topological computation.

The most elegant models of quantum Hall effect are in terms of anyons regarded as singularities due to the symmetry breaking of gauge group G down to a finite sub-group H, which can be also non-Abelian. Concerning the description of the dynamics of topological degrees of freedom topological quantum field theories based on Chern-Simons action are the most promising approach.

Quantum Hall effect

Quantum Hall effect [D16, D10] occurs in 2-dimensional systems, typically a slab carrying a longitudinal voltage V causing longitudinal current j. A magnetic field orthogonal to the slab generates a transversal current component j_T by Lorentz force. j_T is proportional to the voltage V along the slab and the dimensionless coefficient is known as transversal conductivity. Classically the coefficients is proportional ne/B, where n is 2-dimensional electron density and should have a continuous spectrum. The finding that came as surprise was that the change of the coefficient as a function of parameters like magnetic field strength and temperature occurred as discrete steps of same size. In integer quantum Hall effect the coefficient is quantized to $2\nu\alpha$, $\alpha = e^2/4\pi$, such that ν is integer.

Later came the finding that also smaller steps corresponding to the filling fraction $\nu = 1/3$ of the basic step were present and could be understood if the charge of electron would have been replaced with $\nu = 1/3$ of its ordinary value. Later also QH effect with wide large range of filling fractions of form $\nu = k/m$ was observed.

The model explaining the QH effect is based on pseudo particles known as anyons [A26], [D10]. According to the general argument of [D16] anyons have fractional charge νe. Also the TGD based model for fractionization to be discussed later suggests that the anyon charge should be νe quite generally. The braid statistics of anyon is believed to be fractional so that anyons are neither bosons nor fermions. Non-fractional statistics is absolutely essential for the vacuum degeneracy used to represent logical qubits.

In the case of Abelian anyons the gauge potential corresponds to the vector potential of the divergence free velocity field or equivalently of incompressible anyon current. For non-Abelian anyons the field theory defined by Chern-Simons action is free field theory and in well-defined sense trivial although it defines knot invariants. For non-Abelian anyons situation would be different. They would carry non-Abelian gauge charges possibly related to a symmetry breaking to a discrete subgroup H of gauge group [A26] each of them defining an incompressible hydrodynamical flow. Non-Abelian QH effect has not yet been convincingly demonstrated experimentally. According to [B24] the anyons associated with the filling fraction $\nu = 5/2$ are a good candidate for non-Abelian anyons and in this case the charge of electron is reduced to $Q = 1/4$ rather than being $Q = \nu e$.

Non-Abelian anyons [D10, D11] are always created in pairs since they carry a conserved topological charge. In the model of [B24] this charge should have values in 4-element group Z_4 so that it is conserved only modulo 4 so that charges +2 and -2 are equivalent as are also charges 3 and -1. The state of n anyon pairs created from vacuum can be show to possess 2^{n-1}-dimensional vacuum degeneracy [D12]: later a TGD based argument for why this is the case is constructed. When two anyons fuse the 2^{n-1}-dimensional state space decomposes to 2^{n-2}-dimensional tensor factors corresponding to anyon Cooper pairs with topological charges 2 and 0. The topological "spin" is ideal for representing logical qubits. Since free topological charges are not possible the notion of physical qubit does not make sense (note the analogy with quarks). The measurement of topological qubit reduces to a measurement of whether anyon Cooper pair has vanishing topological charge or not.

Quantum Hall effect as a spontaneous symmetry breaking down to a discrete subgroup of the gauge group

The system exhibiting quantum Hall effect is effectively 2-dimensional. Fractional statistics suggests that topological defects, anyons, allowing a description in terms of the representations of the homotopy group of $((R^2)^n - D)/S_n$. The gauge theory description would be in terms of spontaneous symmetry breaking of the gauge group G to a finite subgroup H by a Higgs mechanism [A26] , [D10]. This would make all gauge degrees of freedom massive and leave only topological degrees of freedom. What is unexpected that also non-Abelian topological degrees of freedom are in principle possible. Quantum Hall effect is Abelian or non-Abelian depending on whether the group H has this property.

In the symmetry breaking $G \to H$ the non-Abelian gauge fluxes defined as non-integrable phase factors $Pexp(i \oint A_\mu dx^\mu)$ around large circles (surrounding singularities (so that field approaches a pure gauge configuration) are elements of the first homotopy group of G/H, which is H in the case that H is discrete group and G is simple. An idealized manner to model the situation [D10] is to assume that the connection is pure gauge and defined by an H-valued function which is many-valued such that the values for different branches are related by a gauge transformation in H. In the general case a gauge transformation of a non-trivial gauge field by a multi-valued element of the gauge group would give rise to a similar situation.

One can characterize a given topological singularity magnetically by an element in conjugacy class C of H representing the transformation of H induced by a 2π rotation around singularity. The elements of C define states in given magnetic representation. Electrically the particles are characterized by an irreducible representations of the subgroup of $H_C \subset H$ which commutes with an arbitrarily chosen element of the conjugacy class C.

The action of $h(B)$ resulting on particle A when it makes a closed turn around B reduces in magnetic degrees of freedom to translation in conjugacy class combined with the action of element of H_C in electric degrees of freedom. Closed paths correspond to elements of the braid group $B_n(X^2)$ identifiable as the mapping class group of the punctured 2-surface X^2 and this means that symmetry breaking $G \to H$ defines a representation of the braid group. The construction of these representations is discussed in [D10] and leads naturally via the group algebra of H to the so called quantum double $D(H)$ of H, which is a quasi-triangular Hopf algebra allowing non-trivial representations of braid group.

Anyons could be singularities of gauge fields, perhaps even non-Abelian gauge fields, and the latter ones could be modelled by these representations. In particular, braid operations could be represented using anyons.

Witten-Chern-Simons action and topological quantum field theories

The Wess-Zumino-Witten action used to model 2-dimensional critical systems consists of a 2-dimensional conformally invariant term for the chiral field having values in group G combined with 2+1-dimensional term defined as the integral of Chern-Simons 3-form over a 3-space containing 2-D space as its boundary. This term is purely topological and identifiable as winding number for the map from 3-dimensional space to G. The coefficient of this term is integer k in suitable normalization. k gives the value of central extension of the Kac-Moody algebra defined by the theory.

One can couple the chiral field $g(x)$ to gauge potential defined for some subgroup of G_1 of G. If the G_1 coincides with G, the chiral field can be gauged away by a suitable gauge transformation and the theory becomes purely topological Witten-Chern-Simons theory. Pure gauge field configuration represented either as flat gauge fields with non-trivial holonomy over homotopically non-trivial paths or as multi-valued gauge group elements however remain and the remaining degrees of freedom correspond to the topological degrees of freedom.

Witten-Chern-Simons theories are labelled by a positive integer k giving the value of central extension of the Kac-Moody algebra defined by the theory. The connection with Wess-Zumino-Witten theory come from the fact that the highest weight states associated with the representations of the Kac-Moody algebra of WZW theory are in one-one correspondence with the representations R_i possible for Wilson loops in the topological quantum field theory.

In the Abelian case case 2+1-dimensional Chern-Simons action density is essentially the

inner product $A \wedge dA$ of the vector potential and magnetic field known as helicity density and the theory in question is a free field theory. In the non-Abelian case the action is defined by the 3-form

$$\frac{k}{4\pi} Tr\left(A \wedge (dA + \frac{2}{3} A \wedge A) \right)$$

and contains also interaction term so that the field theory defined by the exponential of the interaction term is non-trivial.

In topological quantum field theory the usual n-point correlation functions defined by the functional integral are replaced by the functional averages for $Diff^3$ invariant quantities defined in terms of non-integrable phase factors defined by ordered exponentials over closed loops. One can consider arbitrary number of loops which can be knotted, linked, and braided. These quantities define both knot and 3-manifold invariants (the functional integral for zero link in particular). The perturbative calculation of the quantum averages leads directly to the Gaussian linking numbers and infinite number of perturbative link and not invariants.

The experience gained from topological quantum field theories defined by Chern-Simons action has led to a very elegant and surprisingly simple category theoretical approach to the topological quantum field theory [A8, A29] allowing to assign invariants to knots, links, braids, and tangles and also to 3-manifolds for which braids as morphisms are replaced with cobordisms. The so called modular Hopf algebras, in particular quantum groups $Sl(2)_q$ with q a root of unity, are in key role in this approach. Also the connection between links and 3-manifolds can be understood since closed, oriented, 3-manifolds can be constructed from each other by surgery based on links.

Witten's article [A12] "Quantum Field Theory and the Jones Polynomial" is full of ingenious constructions, and for a physicist it is the easiest and certainly highly enjoyable manner to learn about knots and 3-manifolds. For these reasons a little bit more detailed sum up is perhaps in order.

1. Witten discusses first the quantization of Chern-Simons action at the weak coupling limit $k \to \infty$. First it is shown how the functional integration around flat connections defines a topological invariant for 3-manifolds in the case of a trivial Wilson loop. Next a canonical quantization is performed in the case $X^3 = \Sigma^2 \times R^1$: in the Coulomb gauge $A_3 = 0$ the action reduces to a sum of $n = dim(G)$ Abelian Chern-Simons actions with a non-linear constraint expressing the vanishing of the gauge field. The configuration space consists thus of flat non-Abelian connections, which are characterized by their holonomy groups and allows Kähler manifold structure.

2. Perhaps the most elegant quantal element of the approach is the decomposition of the 3-manifold to two pieces glued together along 2-manifold implying the decomposition of the functional integral to a product of functional integrals over the pieces. This together with the basic properties of Hilbert of complex numbers (to which the partition functions defined by the functional integrals over the two pieces belong) allows almost a miracle like deduction of the basic results about the behavior of 3-manifold and link invariants under a connected sum, and leads to the crucial skein relations allowing to calculate the invariants by decomposing the link step by step to a union of unknotted, unlinked Wilson loops, which can be calculated exactly for $SU(N)$. The decomposition by skein relations gives rise to a partition function like representation of invariants and allows to understand the connection between knot theory and statistical [A32]. A direct relationship with conformal field theories and Wess-Zumino-Witten model emerges via Wilson loops associated with the highest weight representations for Kac Moody algebras.

3. A similar decomposition procedure applies also to the calculation of 3-manifold invariants using link surgery to transform 3-manifolds to each other, with 3-manifold invariants being defined as Wilson loops associated with the homology generators of these (solid) tori using representations R_i appearing as highest weight representations of the loop algebra of torus. Surgery operations are represented as mapping class group operations acting in the Hilbert space defined by the invariants for representations R_i for the original 3-manifold. The outcome is explicit formulas for the invariants of trivial knots and 3-manifold invariant of S^3 for $G = SU(N)$, in terms of which more complex invariants are expressible.

4. For $SU(N)$ the invariants are expressible as functions of the phase $q = exp(i2\pi/(k+N))$ associated with quantum groups. Note that for $SU(2)$ and $k = 3$, the invariants are expressible in terms of Golden Ratio. The central charge $k = 3$ is in a special position since it gives rise to $k + 1 = 4$-vertex representing naturally 2-gate physically. Witten-Chern-Simons theories define universal unitary modular functors characterizing quantum computations [B29].

Chern-Simons action for anyons

In the case of quantum Hall effect the Chern-Simons action has been deduced from a model of electrons as a 2-dimensional incompressible fluid [D13]. Incompressibility requires that the electron current has a vanishing divergence, which makes it analogous to a magnetic field. The expressibility of the current as a curl of a vector potential b, and a detailed study of the interaction Lagrangian leads to the identification of an Abelian Chern-Simons for b as a low energy effective action. This action is Abelian, whereas the anyonic realization of quantum computation would suggest a non-Abelian Chern-Simons action.

Non-Abelian Chern-Simons action could result in the symmetry breaking of a non-Abelian gauge group G, most naturally electro-weak gauge group, to a non-Abelian discrete subgroup H [A26] so that states would be labelled by representations of H and anyons would be characterized magnetically H-valued non-Abelian magnetic fluxes each of them defining its own incompressible hydro-dynamical flow. As will be found, TGD predicts a non-Abelian Chern-Simons term associated with electroweak long range classical fields.

3.2.5 Topological Quantum Computation Using Braids And Anyons

By the general mathematical results braids are able to code all quantum logic operations [B6]. In particular, braids allow to realize any quantum circuit consisting of single particle gates acting on qubits and two particle gates acting on pairs of qubits. The coding of braid requires a classical computation which can be done in polynomial time. The coding requires that each dancer is able to remember its dancing history by coding it into its own state.

The general ideas are following.

1. The ground states of anyonic system characterize the logical qubits, One assumes non-Abelian anyons with Z_4 -valued topological charge so that a system of n anyon pairs created from vacuum allows 2^{n-1}-fold anyon degeneracy [D12]. The system is decomposed into blocks containing one anyonic Cooper pair with $Q_T \in \{2, 0\}$ and two anyons with such topological charges that the net topological charge vanishes. One can say that the states $(0, 1 - 1)$ and $(0, -1, +1))$ represent logical qubit 0 whereas the states $(2, -1, -1)$ and $(2, +1, +1)$ represent logical qubit 1. This would suggest 2^2-fold degeneracy but actually the degeneracy is 2-fold.

   Free physical qubits are not possible and at least four particles are indeed necessarily in order to represent logical qubit. The reason is that the conservation of Z^4 charge would not allow mixing of qubits 1 and 0, in particular the Hadamard 1-gate generating square root of qubit would break the conservation of topological charge. The square root of qubit can be generated only if 2 units of topological charge is transferred between anyon and anyon Cooper pair. Thus qubits can be represented as entangled states of anyon Cooper pair and anyon and the fourth anyon is needed to achieve vanishing total topological charge in the batch.

2. In the initial state of the system the anyonic Cooper pairs have $Q_T = 0$ and the two anyons have opposite topological charges inside each block. The initial state codes no information unlike in ordinary computation but the information is represented by the braid. Of course, also more general configurations are possible. Anyons are assumed to evolve like free particles except during swap operations and their time evolution is described by single particle Hamiltonians.

   Free particle approximation fails when the anyons are too near to each other as during braid operations. The space of logical qubits is realized as k-code defined by the 2^{n-1} ground states, which are stable against local single particle perturbations for $k = 3$ Witten-Chern-Simons action. In the more general case the stability against n-particle perturbations with

$n < [k/2]$ is achieved but the gates would become $[k/2]$-particle gates (for $k = 5$ this would give 6-particle vertices).

3. Anyonic system provides a unitary modular functor as the S-matrix associated with the anyon system whose time evolution is fixed by the pre-existing braid structure. What this means that the S-matrices associated with the braids can be multiplied and thus a unitary representation for the group formed by braids results. The vacuum degeneracy of anyon system makes this representation non-trivial. By the NP complexity of braids it is possible to code any quantum logic operation by a particular braid [B40]. There exists a powerful approximation theorem allowing to achieve this coding classically in polynomial time [B6]. From the properties of the R-matrices inducing gate operations it is indeed clear that two gates can be realized. The Hadamard 1-gate could be realized as 2-gate in the system formed by anyon Cooper pair and anyon.

4. In [B24] the time evolution is regarded as a discrete sequence of modifications of single anyon Hamiltonians induced by swaps [B41]. If the modifications define a closed loop in the space of Hamiltonians the resulting unitary operators define a representation of braid group in a dense discrete sub-group of $U(2^n)$. The swap operation is 2-local operation acting like a 2-gate and induces quantum logical operation modifying also single particle Hamiltonians. What is important that this modification maps the space of the ground states to a new one and only if the modifications correspond to a closed loop the final state is in the same code space as the initial state. What time evolution does is to affect the topological charges of anyon Cooper pairs representing qubits inside the 4-anyon batches defined by the braids.

   In quantum field theory the analog but not equivalent of this description would be following. Quite generally, a given particle in the final state has suffered a unitary transformation, which is an ordered product consisting of two kinds of unitary operators. Unitary single particle operators $U_n = Pexp(i \int_{t_n}^{t_{n+1}} H_0 dt)$ are analogs of operators describing single qubit gate and play the role of anyon propagators during no-swap periods. Two-particle unitary operators $U_{swap} = Pexp(i \int H_{swap} dt)$ are analogous to four-particle interactions and describe the effect of braid operations inducing entanglement of states having opposite values of topological charge but conserving the net topological charge of the anyon pair. This entanglement is completely analogous to spin entanglement. In particular, the braid operation mixes different states of the anyon. The unitary time development operator generating entangled state of anyons and defined by the braid structure represents the operation performed by the quantum circuit and the quantum measurement in the final state selects a particular final state.

5. Formally the computation halts with a measurement of the topological charge of the left-most anyon Cooper pair when the outcome is just single bit. If decay occurs with sufficiently high probability it is concluded that the value of the computed bit is 0, otherwise 1.

3.3 General Implications Of TGD For Quantum Computation

TGD based view about time and space-time could have rather dramatic implications for quantum computation in general and these implications deserve to be discussed briefly.

3.3.1 Time Need Not Be A Problem For Quantum Computations In TGD Universe

Communication with and control of the geometric past is the basic mechanism of intentional action, sensory perception, and long term memory in TGD inspired theory of consciousness. The possibility to send negative energy signals to the geometric past allows also instantaneous computations with respect to subjective time defined by a sequence of quantum jumps. The outcome of computation back to the past where it defines initial values of the next round of iteration. Time would cease to be a limiting factor to computation.

3.3.2 New View About Information

The notion of information is very problematic even in the classical physics and in quantum realm this concept becomes even more enigmatic. TGD inspired theory consciousness has inspired number theoretic ideas about quantum information which are still developing. The standard definition of entanglement entropy relies on the Shannon's formula: $S = -\sum_k p_k log(p_k)$. This entropy is always non-negative and tells that the best one can achieve is entanglement with zero entropy.

The generalization of the notion of entanglement entropy to the p-adic context however led to realization that entanglement for which entanglement probabilities are rational or in an extension of rational numbers defining a finite extension of p-adics allows a hierarchy of entanglement entropies S_p labelled by primes. These entropies are defined as $S_p = -\sum_k p_k log(|p_k|_p)$, where $|p_k|_p$ denotes the p-adic norm of probability. S_p can be negative and in this case defines a genuine information measure. For given entanglement probabilities S_p has a minimum for some value p_0 of prime p, and S_{p_0} could be taken as a measure for the information carried by the entanglement in question whereas entanglement in real and p-adic continua would be entropic. The entanglement with negative entanglement entropy is identified as bound state entanglement.

Since quantum computers by definition apply states for which entanglement coefficients belong to a finite algebraic extension of rational numbers, the resulting states, if ideal, should be bound states. Also finite-dimensional extensions of p-adic numbers by transcendentals are possible. For instance, the extension by the $p-1$ first powers of e (e^p is ordinary p-adic number in R_p). As an extension of rationals this extension would be discrete but infinite-dimensional. Macro-temporal quantum coherence can be identified as being due to bound state formation in appropriate degrees of freedom and implying that state preparation and state function reduction effectively ceases to occur in these degrees of freedom.

Macro-temporal quantum coherence effectively binds a sequence of quantum jumps to single quantum jump so that the effective duration of unitary evolution is stretched from about 10^4 Planck times to arbitrary long time span. Also quantum computations can be regarded as this kind of extended moments of consciousness.

3.3.3 Number Theoretic Vision About Quantum Jump As A Building Block Of Conscious Experience

The generalization of number concept resulting when reals and various p-adic number fields are fused to a book like structure obtaining by gluing them along rational numbers common to all these number fields leads to an extremely general view about what happens in quantum jump identified as basic building block of conscious experience. First of all, the unitary process U generates a formal superposition of states belonging to different number fields including their extensions. Negentropy Maximization Principle [K60] constrains the dynamics of state preparation and state function reduction following U so that the final state contains only rational or extended rational entanglement with positive information content. At the level of conscious experience this process can be interpreted as a cognitive process or analysis leading to a state containing only bound state entanglement serving as a correlate for the experience of understanding. Thus quantum information science and quantum theory of consciousness seem to meet each other.

In the standard approach to quantum computing entanglement is not bound state entanglement. If bound state entanglement is really the entanglement which is possible for quantum computer, the entanglement of qubits might not serve as a universal entanglement currency. That is, the reduction of the general two-particle entanglement to entanglement between N qubits might not be possible in TGD framework.

The conclusion that only bound state entanglement is possible in quantum computation in human time scales is however based on the somewhat questionable heuristic assumption that subjective time has the same universal rate, that is the average increment Δt of the geometric time in single quantum jump does not depend on the space-time sheet, and is of order CP_2 time about 10^4 Planck times. The conclusion could be circumvented if one assumes that Δt depends on the space-time sheet involved: for instance, instead of CP_2 time Δt could be of order p-adic time scale T_p for a space-time sheet labelled by p-adic prime p and increase like $\sqrt{p}$. In this case the unitary operator defining quantum computation would be simply that defining the unitary process U.

3.3.4 Dissipative Quantum Parallelism?

The new view about quantum jump implies that state function reduction and preparation process decomposes into a hierarchy of these processes occurring in various scales: dissipation would occur in quantum parallel manner with each p-adic scale defining one level in the hierarchy. At space-time level this would correspond to almost independent quantum dynamics at parallel space-time sheets labelled by p-adic primes. In particular, dissipative processes can occur in short scales while the dynamics in longer scales is non-dissipative. This would explain why the description of hadrons as dissipative systems consisting of quarks and gluons in short scales is consistent with the description of hadrons as genuine quantum systems in long scales. Dissipative quantum parallelism would also mean that thermodynamics at shorter length scales would stabilize the dynamics at longer length scales and in this manner favor scaled up quantum coherence.

NMR systems [B5] might represent an example about dissipative quantum parallelism. Room temperature NMR (nuclear magnetic resonance) systems use highly redundant replicas of qubits which have very long coherence times. Quantum gates using radio frequency pulses to modify the spin evolution have been implemented, and even effective Hamiltonians have been synthesized. Quantum computations and dynamics of other quantum systems have been simulated and quantum error protocols have been realized. These successes are unexpected since the energy scale of cyclotron states is much below the thermal energy. This has raised fundamental questions about the power of quantum information processing in highly mixed states, and it might be that dissipative quantum parallelism is needed to explain the successes.

Magnetized systems could realize quite concretely the renormalization group philosophy in the sense that the magnetic fields due to the magnetization at the atomic space-time sheets could define a return flux along larger space-time sheets as magnetic flux quanta (by topological flux quantization) defining effective block spins serving as thermally stabilized qubits for a long length scale quantum parallel dynamics. For an external magnetic field $B \sim 10$ Tesla the magnetic length is $L \sim 10$ nm and corresponds to the p-adic length scale $L(k = 151)$. The induced magnetization is $M \sim n\mu^2 B/T$, where n is the density of nuclei and $\mu = ge/2m_p$ is the magnetic moment of nucleus. For solid matter density the magnetization is by a factor ~ 10 weaker than the Earth's magnetic field and corresponds to a magnetic length $L \sim 15$ μm: the p-adic length scale is around $L(171)$. For 10^{22} spins per block spin used for NMR simulations the size of block spin should be $\sim$ 1mm solid matter density so that single block spin would contain roughly 10^6 magnetization flux quanta containing 10^{16} spins each. The magnetization flux quanta serving as logical qubits could allow to circumvent the standard physics upper bound for scaling up of about 10 logical qubits [B5].

3.3.5 Negative Energies And Quantum Computation

In TGD universe space-times are 4-surfaces so that negative energies are possible due to the fact that the sign of energy depends on time orientation (energy momentum tensor is replaced by a collection of conserved momentum currents). This has several implications. Negative energy photons having phase conjugate photons as physical correlates of photons play a key role in TGD inspired theory of consciousness and living matter and there are also indications that magnetic flux tubes structures with negative energies are important.

Negative energies makes possible communications to the geometric past, and time mirror mechanism (see **Fig. ??** in the appendix of this book) involving generation of negative energy photons is the key mechanism of intentional action and plays central role in the model for the functioning of bio-systems. In principle this could allow to circumvent the problems due to the time required by computation by initiating computation in the geometric past and iterating this process. The most elegant and predictive cosmology is that for which the net conserved quantities of the universe vanish due the natural boundary condition that nothing flows into the future light cone through its boundaries representing the moment of big bang.

Also topological quantum field theories describe systems for which conserved quantities associated with the isometries of space-time, such as energy and momentum, vanish. Hence the natural question is whether negative energies making possible zero energy states might also make possible also zero energy quantum computations.

Crossing symmetry and Eastern and Western views about what happens in scattering

The hypothesis that all physical states have vanishing net quantum numbers (Eastern view) forces to interpret the scattering events of particle physics as quantum jumps between different vacua. This interpretation is in a satisfactory consistency with the assumption about existence of objective reality characterized by a positive energy (Western view) if crossing symmetry holds so that WCW spinor fields can be regarded as S-matrix elements between initial state defined by positive energy particles and negative energy state defined by negative energy particles. As a matter fact, the proposal for the S-matrix of TGD at elementary particle level relies on this idea: the amplitudes for the transition from vacuum to states having vanishing net quantum numbers with positive and negative energy states interpreted as incoming and outgoing states are assumed to be interpretable as S-matrix elements.

More generally, one could require that scattering between any pair of states with zero net energies and representing S-matrix allows interpretation as a scattering between positive energy states. This requirement is satisfied if their exists an entire self-reflective hierarchy of S-matrices in the sense that the S-matrix between states representing S-matrices S_1 and S_2 would be the tensor product $S_1 \otimes S_2$. At the observational level the experience the usual sequence of observations $|m_1\rangle \to |m_2\rangle ..... \to |m_n\rangle ...$ based on belief about objective reality with non-vanishing conserved net quantum numbers would correspond to a sequence $(|m_1 \to m_2\rangle \to |m_2 \to m_3\rangle ...$ between "self-reflective" zero energy states. These sequences are expected to be of special importance since the contribution of the unit matrix to S-matrix $S = 1 + iT$ gives dominating contribution unless interactions are strong. This sequence would result in the approximation that $S_2 = 1 + iT_2$ in $S = S_1 \otimes S_2$ is diagonal. The fact that the scattering for macroscopic systems tends to be in forward direction would help to create the materialistic illusion about unique objective reality.

It should be possible to test whether the Eastern or Western view is correct by looking what happens strong interacting systems where the western view should fail. The Eastern view is consistent with the basic vision about quantum jumps between quantum histories having as a counterpart the change of the geometric past at space-time level.

Negative energy anti-fermions and matter-antimatter asymmetry

The assumption that space-time is 4-surface means that the sign of energy depends on time orientation so that negative energies are possible. Phase conjugate photons [D15] are excellent candidates for negative energy photons propagating into geometric past.

Also the phase conjugate fermions make in principle sense and one can indeed perform Dirac quantization in four ways such that a) both fermions and anti-fermions have positive/negative energies, b) fermions (anti-fermions) have positive energies and anti-fermions (fermions) have negative energies. The corresponding ground state correspond to Dirac seas obtained by applying the product of a) all fermionic and anti-fermionic annihilation (creation) operators to vacuum, b) all fermionic creation (annihilation) operators and anti-fermionic annihilation (creation) operators to vacuum. The ground states of a) have infinite vacuum energy which is either negative or positive whereas the ground states of b) have vanishing vacuum energy. The case b) with positive fermionic and negative anti-fermionic energies could correspond to long length scales in which are matter-antisymmetric due to the effective absence of anti-fermions ("effective" meaning that no-one has tried to detect the negative energy anti-fermions). The case a) with positive energies could naturally correspond to the phase studied in elementary particle physics.

If gravitational and inertial masses have same magnitude and same sign, consistency with empirical facts requires that positive and negative energy matter must have been separated in cosmological length scales. Gravitational repulsion might be the mechanism causing this. Applying naïvely Newton's equations to a system of two bodies with energies $E_1 > 0$ and $-E_2 < 0$ and assuming only gravitational force, one finds that the sign of force for the motion in relative coordinates is determined by the sign of the reduced mass $-E_1E_2/(E_1 - E_2)$, which is negative for $E_1 > |E_2|$: positive masses would act repulsively on smaller negative masses. For $E_1 = -E_2$ the motion in the relative coordinate becomes free motion and both systems experience same acceleration which for E_1 corresponds to a repulsive force. The reader has probably already asked whether the observed acceleration of the cosmological expansion interpreted in terms of cosmological constant due to vacuum energy could actually correspond to a repulsive force between positive

and negative energy matter.

It is possible to create pairs of positive energy fermions and negative energy fermions from vacuum. For instance, annihilation of photons and phase conjugate photons could create electron and negative energy positron pairs with a vanishing net energy. Magnetic flux tubes having positive and negative energies carrying fermions and negative energy positrons pairs of photons and their phase conjugates via fermion anti-fermion annihilation. The obvious idea is to perform zero energy topological quantum computations by using anyons of positive energy and anti-anyons of negative energy plus their Cooper pairs. This idea will be discussed later in more detail.

3.4 TGD Based New Physics Related To Topological Quantum Computation

For a long the belief was that absolute minimum property defines the basic dynamical principle of space-time physics. This might make sense in space-time regions of Euclidian signature, where Kähler action is non-negative but not in Minkowskian regions, where the contribution to the exponent defining vacuum functional is imaginary. The reduction of the theory to the level of Kähler-Dirac action [K111] made it however clear that 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 suggest the conclusion that space-time surfaces must be hyper-quaternionic in the sense that the Kähler-Dirac gamma matrices span hyper-quaternionic (asociative) or co-hyper-quaternionic (co-associative) plane at each point of the spacce-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.

For a long time it remained an open question whether the known solutions of field equations are building blocks of preferred extremals of Kähler action or represent only the simplest extremals one can imagine and perhaps devoid of any real significance. Quantum-classical correspondence meant a great progress in the understanding the solution spectrum of field equations. Among other things, this principle requires that the dissipative quantum dynamics leading to non-dissipating asymptotic self-organization patterns should have the vanishing of the Lorentz 4-force as space-time correlate. The absence of dissipation in the sense of vanishing of Lorentz 4-force is a natural correlate for the absence of dissipation in quantum computations.

The vanishing of Lorentz 4-force generalizes the so called Beltrami conditions [B9, B16] stating the vanishing of Lorentz force for purely magnetic field configurations and these conditions reduce in many cases to topological conditions. The study of classical field equations predicts three phases corresponding to non-vacuum solutions of field equations possessing vanishing Lorentz force. The dimension D of CP_2 projection of the space-time sheet serves as classifier of the phases.

1. $D = 2$ phase is analogous to ferro-magnetic phase possible in low temperatures and relatively simple, $D = 4$ phase is in turn analogous to a chaotic de-magnetized high temperature phase.

2. $D = 3$ phase represents spin glass phase, kind of boundary region between order and chaos possible in a finite temperature range and is an ideal candidate for the field body serving as a template for living systems. $D = 3$ phase allows infinite number of conserved topological charges having interpretation as invariants describing the linking of the magnetic field lines. This phase is also the phase in which topological quantum computations are possible.

3.4.1 Topologically Quantized Generalized Beltrami Fields And Braiding

From the construction of the solutions of field equations in terms topologically quantized fields it is obvious that TGD Universe is tailor made for TQC.

$D = 3$ phase allows infinite number of topological charges characterizing the linking of magnetic field lines

When space-time sheet possesses a $D = 3$-dimensional CP_2 projection, one can assign to it a non-vanishing and conserved topological charge characterizing the linking of the magnetic field lines defined by Chern-Simons action density $A \wedge dA/4\pi$ for induced Kähler form. This charge can be seen as classical topological invariant of the linked structure formed by magnetic field lines. For $D = 2$ the topological charge densities vanish identically, for $D = 3$ they are in general non-vanishing and conserved, whereas for $D = 4$ they are not conserved. The transition to $D = 4$ phase can thus be used to erase quantum computer programs realized as braids. The 3-dimensional CP_2 projection provides an economical manner to represent the braided world line pattern of dancers and would be the space where the 3-dimensional quantum field theory would be defined.

The topological charge can also vanish for $D = 3$ space-time sheets. In Darboux coordinates for which Kähler gauge potential reads as $A = P_k dQ^k$, the surfaces of this kind result if one has $Q^2 = f(Q^1)$ implying $A = fdQ^1$, $f = P_1 + P_2\partial_{Q_1}Q^2$, which implies the condition $A \wedge dA = 0$. For these space-time sheets one can introduce Q^1 as a global coordinate along field lines of A and define the phase factor $exp(i \int A_\mu dx^\mu)$ as a wave function defined for the entire space-time sheet. This function could be interpreted as a phase of an order order parameter of super-conductor like state and there is a high temptation to assume that quantum coherence in this sense is lost for more general $D = 3$ solutions. Note however that in boundaries can still remain super-conducting and it seems that this occurs in the case of anyons.

Chern-Simons action is known as helicity in electrodynamics [B32]. Helicity indeed describes the linking of magnetic flux lines as is easy to see by interpreting magnetic field as incompressible fluid flow having A as vector potential: $B = \nabla \times A$. One can write A using the inverse of $\nabla\times$ as $A = (1/\nabla\times)B$. The inverse is non-local operator expressible as

$$\frac{1}{\nabla\times}B(r) = \int dV' \frac{(r - r')}{|r - r'|^3} \times B(r') \quad ,$$

as a little calculation shows. This allows to write $\int A \cdot B$ as

$$\int dV A \cdot B = \int dV dV' B(r) \cdot \left(\frac{(r - r')}{|r - r'|^3} \times B(r') \right) \quad ,$$

which is completely analogous to the Gauss formula for linking number when linked curves are replaced by a distribution of linked curves and an average is taken.

For $D = 3$ field equations imply that Kähler current is proportional to the helicity current by a factor which depends on CP_2 coordinates, which implies that the current is automatically divergence free and defines a conserved charge for $D = 3$-dimensional CP_2 projection for which the instanton density vanishes identically. Kähler charge is not equal to the helicity defined by the inner product of magnetic field and vector potential but to a more general topological charge.

The number of conserved topological charges is infinite since the product of any function of CP_2 coordinates with the helicity current has vanishing divergence and defines a topological charge. A very natural function basis is provided by the scalar spherical harmonics of $SU(3)$ defining Hamiltonians of CP_2 canonical transformations and possessing well defined color quantum numbers. These functions define and infinite number of conserved charges which are also classical knot invariants in the sense that they are not affected at all when the 3-surface interpreted as a map from CP_2 projection to M^4_+ is deformed in M^4_+ degrees of freedom. Also canonical transformations induced by Hamiltonians in irreducible representations of color group affect these invariants via Poisson bracket action when the $U(1)$ gauge transformation induced by the canonical transformation corresponds to a single valued scalar function. These link invariants are additive in union whereas the quantum invariants defined by topological quantum field theories are multiplicative.

Also non-Abelian topological charges are well-defined. One can generalize the topological current associated with the Kähler form to a corresponding current associated with the induced electro-weak gauge fields whereas for classical color gauge fields the Chern-Simons form vanishes identically. Also in this case one can multiply the current by CP_2 color harmonics to obtain an infinite number of invariants in $D = 3$ case. The only difference is that $A \wedge dA$ is replaced by $Tr(A \wedge (dA + 2A \wedge A/3))$.

There is a strong temptation to assume that these conserved charges characterize colored quantum states of the conformally invariant quantum theory as a functional of the light-like 3-surface defining boundary of space-time sheet or elementary particle horizon surrounding wormhole contacts. They would be TGD analogs of the states of the topological quantum field theory defined by Chern-Simons action as highest weight states associated with corresponding Wess-Zumino-Witten theory. These charges could be interpreted as topological counterparts of the isometry charges of WCW of 3-surfaces defined by the algebra of canonical transformations of CP_2.

The interpretation of these charges as contributions of light-like boundaries to WCW Hamiltonians would be natural. The dynamics of the induced second quantized spinor fields relates to that of Kähler action by a super-symmetry, so that it should define super-symmetric counterparts of these knot invariants. The anti-commutators of these super charges would contribute to WCW metric a part which would define a Kähler magnetic knot invariant. These Hamiltonians and their super-charge counterparts would be responsible for the topological sector of quantum TGD.

The color partial wave degeneracy of topological charges inspires the idea that also anyons could move in color partial waves identifiable in terms of "rigid body rotation" of the magnetic flux tube of anyon in CP_2 degrees of freedom. Their presence could explain non-Abelianity of Chern-Simons action and bring in new kind bits increasing the computational capacity of the topological quantum computer. The idea about the importance of macroscopic color is not new in TGD context. The fact that non-vanishing Kähler field is always accompanied by a classical color field (proportional to it) has motivated the proposal that colored excitations in macroscopic length scales are important in living matter and that colors as visual qualia correspond to increments of color quantum numbers in quantum phase transitions giving rise to visual sensations.

Knot theory, 3-manifold topology, and $D = 3$ solutions of field equations

Topological quantum field theory (TQFT) [A29] demonstrates a deep connection between links and 3-topology, and one might hope that this connection could be re-interpreted in terms of embeddings of 3-manifolds to $H = M^4_+ \times CP_2$ as surfaces having 3-dimensional CP_2 projection, call it X^3 in the sequel. $D = 3$ suggests itself because in this case Chern-Simons action density for the induced Kähler field is generically non-vanishing and defines an infinite number of classical charges identifiable as Kähler magnetic canonical covariants invariant under $Diff(M^4_+)$. The field topology of Kähler magnetic field should be in a key role in the understanding of these invariants.

1. Could 3-D CP_2 projection of 3-surface provide a representation of 3-topology?

Witten-Chern-Simons theory for a given 3-manifold defines invariants which characterize both the topology of 3-manifold and the link. Why this is the case can be understood from the construction of 3-manifolds by drilling a tubular neighborhood of a link in S^3 and by gluing the tori back to get a new 3-manifolds. The links with some moves defining link equivalences are known to be in one-one correspondence with closed 3-manifolds and the axiomatic formulation of TQFT [A29] as a modular functor clarifies this correspondence. The question is whether the CP_2 projection of the 3-surface could under some assumptions be represented by a link so that one could understand the connection between the links and topology of 3-manifolds.

In order to get some idea about what might happen consider the CP_2 projection X^3 of 3-surface. Assume that X^3 is obtained from S^3 represented as a 3-surface in CP_2 by removing from S^3 a tubular link consisting of linked and knotted solid tori $D^2 \times S^1$. Since the 3-surface is closed, it must have folds at the boundaries being thus representable as a two-valued map $S^3 \to M^4_+$ near the folds. Assume that this is the case everywhere. The two halves of the 3-surface corresponding to the two branches of the map would be glued together along the boundary of the tubular link by identification maps which are in the general case characterized by the mapping class group of 2-torus. The gluing maps are defined inside the overlapping coordinate batches containing the boundary $S^1 \times S^1$ and are maps between the pairs (Ψ_i, Φ_i), $i = 1, 2$ of the angular coordinates parameterizing the tori.

Define longitude as a representative for the $a + nb$ of the homology group of the 2-torus. The integer n defines so called framing and means that the longitude twists n times around torus. As a matter fact, TQFT requires bi-framing: at the level of Chern-Simons perturbation theory bi-framing is necessary in order to define self linking numbers. Define meridian as the generator of the homology group of the complement of solid torus in S^3. It is enough to glue the carved torus

back in such a way that meridian is mapped to longitude and longitude to minus meridian. This map corresponds to the $SL(2,C)$ element

$$\begin{pmatrix} 0 & 1 \\ -1 & 0 \end{pmatrix} .$$

Also other identification maps defined by $SL(2,Z)$ matrices are possible but one can do using only this. Note that the two component $SL(2,Z)$ spinors defined as superpositions of the generators (a,b) of the homology group of torus are candidates for the topological correlates of spinors. In the gluing process the tori become knotted and linked when seen in the coordinates of the complement of the solid tori.

This construction would represent the link surgery of 3-manifolds in terms of CP_2 projections of 3-surfaces of H. Unfortunately this representation does not seem to be the only one. One can construct closed three-manifolds also by the so called Heegaard splitting. Remove from S^3 D_g, a solid sphere with g handles having boundary S_g, and glue the resulting surface with its oppositely oriented copy along boundaries. The gluing maps are classified by the mapping class group of S_g. Any closed orientable 3-manifold can be obtained by this kind of procedure for some value of g. Also this construction could be interpreted in terms of a fold at the boundary of the CP_2 projection for a 2-valued graph $S^3 \to M^4_+$. Whether link surgery representation and Heegaard splitting could be transformed to each other by say pinching D_g to separate tori is not clear to me.

When the graph $CP_2 \to M^4_+$ is at most 2-valued, the intricacies due to the embedding of the 3-manifold are at minimum, and the link associated with the projection should give information about 3-topology and perhaps even characterize it. Also the classical topological charges associated with Kähler Chern-Simons action could give this kind of information.

2. Knotting and linking for 3-surfaces

The intricacies related to embedding become important in small co-dimensions and it is of considerable interest to find what can happen in the case of 3-surfaces. For 1-dimensional links and knots the projection to a plane, the shadow of the knot, characterizes the link/knot and allows to deduce link and knot invariants purely combinatorially by gradually removing the intersection points and writing a contribution to the link invariant determined by the orientations of intersecting strands and by which of them is above the other. Thus also the generalization of knot and link diagrams is of interest.

Linking of m- and n-dimensional sub-manifolds of D-dimensional manifold H_D occurs when the condition $m + n = D - 1$ holds true. The n-dimensional sub-manifold intersects $m + 1$-dimensional surfaces having m-dimensional manifold as its boundary at discrete points, and it is usually not possible to remove these points by deforming the surfaces without intersections in some intermediate stage. The generalization of the link diagram results as a projection $D-1$-dimensional disk D^{D-1} of H_D.

3-surfaces link in dimension $D = 7$ so that the linking of 3-surfaces occurs quite generally in time=constant section of the embedding space. A link diagram would result as a projection to $E^2 \times CP_2$, E^2 a 2-dimensional plane: putting CP_2 coordinates constant gives ordinary link diagram in E^2. For magnetic flux tubes the reduction to 2-dimensional linking by idealizing flux tubes with 1-dimensional strings makes sense.

Knotting occurs in codimension 2 that is for an n-manifold imbedded in $D = n + 2$-dimensional manifold. Knotting can be understood as follows. Knotted surface spans locally $n + 1$-dimensional 2-sided n+1-disk D^{n+1} (disk for ordinary knot). The portion of surface going through D^{n+1} can be idealized with a 1-dimensional thread going through it and by $n+2 = D$ knotting is locally linking of this 1-dimensional thread with n-dimensional manifold. N-dimensional knots define n+1-dimensional knots by so called spinning. Take an n-knot with the topology of sphere S^n such that the knotted part is above $n+1$-plane of $n+2$-dimensional space R^{n+2} ($z \geq 0$), cut off the part below plane ($z < 0$), introduce an additional dimension (t) and make a 2π rotation for the resulting knot in $z - t$ plane. The resulting manifold is a knotted S^{n+1}. The counterpart of the knot diagram would be a projection to $n + 1$-dimensional sub-manifold, most naturally disk D^{n+1}, of the embedding space.

3-surfaces could become knotted under some conditions. Vacuum extremals correspond to 4-surfaces $X^4 \subset M^4_+ \times Y^2$ whereas the four-surfaces $X^4 \subset M^4_+ \times S^2$, S^2 homologically non-trivial

geodesic sphere, define their own "sub-theory". In both cases 3-surfaces in time=constant section of embedding space can get knotted in the sense that un-knotting requires giving up the defining condition temporarily. The counterpart of the knot diagram is the projection to $E^2 \times X^2$, $X^2 = Y^2$ or S^2, where E^2 is plane of M^4_+. For constant values of CP_2 coordinates ordinary knot diagram would result. Reduction to ordinary knot diagrams would naturally occur for $D = 2$ magnetic flux tubes. The knotting occurs also for 4-surfaces themselves in $M^4_+ \times X^2$: knot diagram is now defined as projection to $E^3 \times X^2$.

3. Could the magnetic field topology of 3-manifold be able to mimic other 3-topologies?

In $D = 3$ case the topological charges associated with Kähler Chern-Simons term characterize the linking of the field lines of the Kähler gauge potential A. What $dA \wedge A \neq 0$ means that field lines are linked and it is not possible to define a coordinate varying along the field lines of A. This is impossible even locally since the $dA \wedge A \neq 0$ condition is equivalent with non existence of a scalar functions k and Φ such that $\nabla\Phi = kA$ guaranteeing that Φ would be the sought for global coordinate.

One can idealize the situation a little bit and think of a field configuration for which magnetic flux is concentrated at one-dimensional closed lines. The vector potential would in this case be simply $A = \nabla(k\Psi + l\Phi)$, where Ψ is an angle coordinate around the singular line and Φ a coordinate along the singular circle. In this idealized situation the failure to have a global coordinate would be due to the singularities of otherwise global coordinates along one-dimensional linked and knotted circles. The reason is that the field lines of A and B rotate helically around the singular circle and the points (x, y, z) with constant values of x, y are on a helix which becomes singular at z-axis. Since the replacement of a field configuration with a non-singular field configuration but having same field line topology does not affect the global field line topology, one might hope of characterizing the field topology by its singularities along linked and knotted circles also in the general case.

Just similar linked and knotted circles are used to construct 3-manifolds in the link surgery which would suggest that the singularities of the field line topology of X^3 code the non-trivial 3-topology resulting when the singularities are removed by link surgery. Physically the longitude defining the framing $a + nb$ would correspond to the field line of A making an $n2\pi$ twist along the singular circle. Meridian would correspond to a circle in the plane of B. The bi-framing necessitated by TQFT would have a physical interpretation in terms of the helical field lines of A and B rotating around the singular circle. At the level of fields the gluing operation would mean a gauge transformation such that the meridians would become the field lines of the gauge transformed A and being non-helical could be continued to the interior of the glued torus without singularities. Simple non-helical magnetic torus would be in question.

This means that the magnetic field patterns of a given 3-manifold could mimic the topologies of other 3-manifolds. The topological mimicry of this kind would be a very robust manner to represent information and might be directly relevant to TQC. For instance, the computation of topological invariants of 3-manifold Y^3 could be coded by the field pattern of X^3 representing the link surgery producing the 3-manifold from S^3, and the physical realization of TQC program could directly utilize the singularities of this field pattern. Topological magnetized flux tubes glued to the back-ground 3-surface along the singular field lines of A could provide the braiding.

This mimicry could also induce transitions to the new topology and relate directly to 3-manifold surgery performed by a physical system. This transition would quite concretely mean gluing of simple $D = 2$ magnetic flux tubes along their boundaries to the larger $D = 3$ space-time sheet from which similar flux tube has been cut away.

4. A connection with anyons?

There is also a possible connection with anyons. Anyons are thought to correspond to singularities of gauge fields resulting in a symmetry breaking of gauge group to a finite subgroup H and are associated with homotopically non-trivial loops of $C_n = ((R^2)^n - D)/S_n$ represented as elements of H. Could the singularities of gauge fields relate to the singularities of the link surgery so that the singularities would be more or less identifiable as anyons? Could N-branched anyons be identified in terms of framings $a + Nb$ associated with the gluing map? $D = 3$ solutions allow the so called contact structure [K15], which means a decomposition of the coordinates of CP_2 projection to a longitudinal coordinate s and a complex coordinate w. Could this decomposition

generalize the notion of effective 2-dimensionality crucial for the notion of anyon?

5. What about Witten's quantal link invariants?

Witten's quantal link invariants define natural multiplicative factors of WCW spinor fields identifiable as representations of two 2-dimensional topological evolution. In Witten's approach these invariants are defined as functional averages of non-integrable phase factors associated with a given link in a given 3-manifold. TGD does not allow any natural functional integral over gauge field configurations for a fixed 3-surface unless one is willing to introduce fictive non-Abelian gauge fields. Although this is not a problem as such, the representation of the invariants in terms of inherent properties of the 3-surface or corresponding 4-surfaces would be highly desirable.

Functional integral representation is not the only possibility. Quantum classical correspondence combined with topological field quantization implied by the preferred extremal property generalizing Bohr rules to the field context gives hopes that the 3-surfaces themselves might be able to represent 3-manifold invariants classically. In $D = 3$ case the quantized exponents of Kähler-Chern-Simons action and $SU(2)_L$ Chern-Simons action could define 3-manifold invariants. These invariants would satisfy the obvious multiplicativity conditions and could correspond to the phase factors due to the framing dependence of Witten's invariants identifying the loops of surgery link as Wilson loops. These phase factors are powers of $U = exp(i2\pi c/24)$, where c is the central charge of the Virasoro representation defined by Kac Moody representation. One has $c = k \times dim(g)/(k + c_g/2)$, which gives $U = exp(i2\pi k/8(k + 2))$ for $SU(2)$. The dependence on k differs from what one might naïvely expect. For this reason, and also because the classical Wilson loops do not depend explicitly on k, the value of k appearing in Chern-Simons action should be fixed by the internal consistency and be a constant of Nature according to TGD. The guess is that k possesses the minimal value $k = 3$ allowing a universal modular functor for $SU(2)$ with $q = exp(i2\pi/5)$.

The loops associated with the topological singularities of the Kähler gauge potential (typically the center lines of helical field configurations) would in turn define natural Wilson loops, and since the holonomies around these loops are also topologically quantized, they could define invariants of 3-manifolds obtained by performing surgery around these lines. The behavior of the induced gauge fields should be universal near the singularities in the sense that the holonomies associated with the CP_2 projections of the singularities to CP_2 would be universal. This expectation is encouraged by the notion of quantum criticality in general and in particular, by the interpretation of $D = 3$ phase as a critical system analogous to spin glass.

The exponent of Chern-Simons action can explain only the phase factors due to the framing, which are usually regarded as an unavoidable nuisance. This might be however all that is needed. For the manifolds of type $X^2 \times S^1$ all link invariants are either equal to unity or vanish. Surgery would allow to build 3-manifold invariants from those of $S^2 \times S^1$. For instance, surgery gives the invariant $Z(S^3)$ in terms of $Z(S^2 \times S^1, R_i)$ and mapping class group action coded into the linking of the field lines.

Holonomies can be also seen as multi-valued $SU(2)_L$ gauge transformations and can be mapped to a multi-valued transformations in the $SU(2)$ subgroup of $SU(3)$ acting on 3-surface as a geometric transformations and making it multi-branched. This makes sense if the holonomies define a finite group so that the gauge transformation is finitely many-valued. This description might apply to the 3-manifold resulting in a surgery defined by the Wilson loops identifiable as branched covering of the initial manifold.

The construction makes also sense for the holonomies defined by the classical $SU(3)$ gauge fields defined by the projections of the isometry currents. Furthermore, the fact that any CP_2 Hamiltonian defines a conserved topological charge in $D = 3$ phase should have a deep significance. At the level of WCW geometry the finite-dimensional group defining Kac Moody algebra is replaced with the group of canonical transformations of CP_2. Perhaps one could extend the notion of Wilson loop for the algebra of canonical transformations of CP_2 so that the representations R_i of the gauge group would be replaced by matrix representations of the canonical algebra. That the trace of the identity matrix is infinite in this case need not be a problem since one can simply redefine the trace to have value one.

Braids as topologically quantized magnetic fields

$D = 3$ space-time sheets would define complex braiding structures with flux tubes possessing infinite number of topological charges characterizing the linking of field lines. The world lines of the quantum computing dancers could thus correspond to the flux tubes that can get knotted, linked, and braided. This idea conforms with the earlier idea that the various knotted and linked structures formed by linear bio-molecules define some kind of computer programs.

1. Boundaries of magnetic flux tubes as light-like 3-surfaces

Field equations for Kähler action are satisfied identically at boundaries if the boundaries of magnetic flux tubes (and space-time sheet in general) are light-like in the induced metric. In M^4_+ metric the flux tubes could look static structures. Light-likeness allows an interpretation of the boundary state either as a 3-dimensional quantum state or as a time-evolution of a 2-dimensional quantum state. This conforms with the idea that quantum computation is cognitive, self reflective process so that quantum state is about something rather than something. There would be no need to force particles to flow through the braid structure to build up time-like braid whereas for time-like boundaries of magnetic flux tubes a time-like braid results only if the topologically charged particles flow through the flux tubes with the same average velocity so that the length along flux tubes is mapped to time.

Using the terminology of consciousness theory, one could say that during quantum dance the dancers are in trance being entangled to a single macro-temporally coherent state which represents single collective consciousness, and wake up to individual dancers when the dance ends. Quantum classical correspondence suggests that the generation of bound state entanglement between dancers requires tangled flux tubes connecting the space-time sheets of anyons (braid of flux tubes again!): dancers share mental images whereas direct contact between magnetic flux tubes defining the braid is not necessary. The bound state entanglement between sub-systems of unentangled systems is made possible by the many-sheeted space-time. This kind of entanglement could be interpreted as entanglement not visible in scales of larger flux tubes so that the notion is natural in the philosophy based on the idea of length scale resolution.

2. How braids are generated?

The encoding of the program to a braid could be a mechanical process: a bundle of magnetic flux tubes with one end fixed would be gradually weaved to a braid by stretching and performing the needed elementary twists. The time to perform the braiding mechanically requires classical computer program and the time needed to carry out the braiding depends polynomially on the number of strands.

The process could also occur by a quantum jump generating the braided flux tubes in single flash and perhaps even intentionally in living systems (flux tubes with negative topological charge could have negative energy so that it would require no energy to generate the structure from vacuum). The interaction with environment could be used to select the desired braids. Also ensembles of braids might be imagined. Living matter might have discovered this mechanism and used int intentionally.

3. Topological quantization, many-sheetedness, and localization

Localization of modular functors is one of the key problems in topological quantum computation (see the article of Freedman [B41]. For anyonic computation this would mean in the ideal case a decomposition of the system into batches containing 4 anyons each so that these anyon groups interact only during swap operations.

The role of topological quantization would be to select of a portion of the magnetic field defining the braid as a macroscopic structure. Topological field quantization realizes elegantly the requirement that single particle time evolutions between swaps involve no interaction with other anyons.

Also many-sheetedness is important. The (AA) pair and two anyons would correspond braids inside braids and as it turns out this gives more flexibility in construction of quantum computation since the 1-gates associated with logical qubits of 4-batch can belong to different representation of braid group than that associated with braiding of the batches.

3.4.2 Quantum Hall Effect And Fractional Charges In TGD

In fractional QH effect anyons possess fractional electromagnetic charges. Also fractional spin is possible. TGD explains fractional charges as being due to multi-branched character of space-time sheets. Also the Z_n-valued topological charge associated with anyons has natural explanation.

Basic TGD inspired ideas about quantum Hall effect

Quantum Hall effect is observed in low temperature systems when the intensity of a strong magnetic field perpendicular to the current carrying slab is varied adiabatically. Classically quantum Hall effect can be understood as a generation of a transversal electric field, which exactly cancels the magnetic Lorentz force. This gives $E = -j \times B/ne$. The resulting current can be also understood as due to a drift velocity proportional to $E \times B$ generated in electric and magnetic fields orthogonal to each other and allowing to cancel Lorentz force. This picture leads to the classical expression for transversal Hall conductivity as $\sigma_{xy} = ne/B$. σ_{xy} should vary continuously as a function of the magnetic field and 2-dimensional electron density n.

In quantum Hall effect σ_{xy} is piece-wise constant and quantized with relative precision of about 10^{-10}. The second remarkable feature is that the longitudinal conductivity σ_{xx} is very high at plateaus: variations by 13 orders of magnitude are observed. The system is also very sensitive to small perturbations.

Consider now what these qualitative observations might mean in TGD context.

1. Sensitivity to small perturbations means criticality. TGD Universe is quantum critical and quantum criticality reduces to the spin glass degeneracy due to the enormous vacuum degeneracy of the theory. The $D = 2$ and $D = 3$ non-vacuum phases predicted by the generalized Beltrami ansatz are this in-stability might play important role in the effect.

2. The magnetic fields are genuinely classical fields in TGD framework, and for $D = 2$ proportional to induced Kähler magnetic field. The canonical symmetries of CP_2 act like $U(1)$ gauge transformations on the induced gauge field but are not gauge symmetries since canonical transformations change the shape of 3-surface and affect both classical gravitational fields and electro-weak and color gauge fields. Hence different gauges for classical Kähler field represent magnetic fields for which topological field quanta can have widely differing and physically non-equivalent shapes. For instance, tube like quanta act effectively as insulators whereas magnetic walls parallel to the slab act as conducting wires.

   Wall like flux tubes parallel to the slab perhaps formed by a partial fusion of magnetic flux tubes along their boundaries would give rise to high longitudinal conductivity. For disjoint flux tubes the motion would be around the flux tubes and the electrons would get stuck inside these tubes. By quantum criticality and by $D < 4$ property the magnetic flux tube structures are unstable against perturbations, in particular the variation of the magnetic field strength itself. The transitions from a plateau to a new one would correspond to the decay of the magnetic walls back to disjoint flux tubes followed by a generation of walls again so that conductivity is very high outside transition regions. The variation of any parameter, such as temperature, is expected to be able to cause similar effects implying dramatic changes in Hall conductivity.

   The percolation model for the quantum Hall effect represents slab as a landscape with mountains and valleys and the varied external parameter, say B or free electron density, as the sea level. For the critical values of sea level narrow regions carrying so called edge states allow liquid to fill large regions appear and implies increase of conductivity. Obviously percolation model differs from the model based on criticality for which the landscape itself is highly fragile and a small perturbation can develop new valleys and mountains.

3. The effective 2-dimensionality implies that the solutions of Schrödinger equation of electron in external magnetic field are products of any analytic function with a Gaussian representing the ground state of a harmonic oscillator. Analyticity means that the kinetic energy is completely degenerate for these solutions. The Lauhglin ansatz for the state functions of electron in the external magnetic field is many-electron generalization of these solutions: the

wave functions consists of products of terms of form $(z_i - z_j)^m$, m odd integer from Fermi statistics.

The N-particle variant of Laughlin's ansatz allows to deduce that the system is incompressible. The key observation is that the probability density for the many-particle state has an interpretation as a Boltzmann factor for a fictive two-dimensional plasma in electric field created by constant charge density [D16, D13]. The probability density is extremely sensitive to the changes of the positions of electrons giving rise to the constant electron density. The screening of charge in this fictive plasma implies the filling fraction $\nu = 1/m$, m odd integer and requires charge fractionization $e \to e/m$. The explanation of the filling fractions $\nu = N/m$ would require multi-valued wave functions $(z_i - z_j)^{N/m}$. In single-sheeted space-time this leads to problems. TGD suggests that these wave functions are single valued but defined on N-branched surface.

The degeneracy with respect to kinetic energy brings in mind the spin glass degeneracy induced by the vacuum degeneracy of the Kähler action. The Dirac equation for the induced spinors is not ordinary Dirac equation but super-symmetrically related to the field equations associated with Kähler action. Also it allows vacuum degeneracy. One cannot exclude the possibility that also this aspect is involved at deeper level.

4. The fractionization of charge in quantum Hall effect challenges the idea that charged particles of the incompressible liquid are electrons and this leads to the notion of anyon. Quantum-classical correspondence inspires the idea that although dissipation is absent, it has left its signature as a track associated with electron. This track is magnetic flux tube surrounding the classical orbit of electron and electron is confined inside it. This reduces the dissipative effects and explains the increase of conductivity. The rule that there is single electron state per magnetic flux quantum follows if Bohr quantization is applied to the radii of the orbits. The fractional charge of anyon would result from a contribution of classical Kähler charge of anyon flux tube to the charge of the anyon. This charge is topologized in $D = 3$ phase.

Anyons as multi-branched flux tubes representing charged particle plus its track

Electrons (in fact, any charged particles) moving inside magnetic flux tubes move along circular paths classically. The solutions of the field equations with vanishing Lorentz 4-force correspond to asymptotic patterns for which dissipation has already done its job and is absent. Dissipation has however definite effects on the final state of the system, and one can argue that the periodic motion of the charged particle has created what might called its "track". The track would be realized as a circular or helical flux tube rotating around field lines of the magnetic field. The corresponding cyclotron states would be localized inside tracks. Simplest tracks are circular ones and correspond to absence of motion in the direction of the magnetic field. Anyons could be identified as systems formed as particles plus the tracks containing them.

1. Many-branched tracks and approach to chaos

When the system approaches chaos one expects the periodic circular tracks become non-periodic. One however expects that this process occurs in steps so that the tracks are periodic in the sense that they close after N 2π rotations with the value of N increasing gradually. The requirement that Kähler energy stays finite suggests also this. A basic example of this kind of track is obtained when the phase angles Ψ and Φ of complex CP_2 coordinates (ξ^1, ξ^2) have finitely multi-valued dependence on the coordinate ϕ of cylindrical coordinates: $(\Psi, \Phi) = (m_1/N, m_2/N)\phi)$. The space-sheet would be many-branched and it would take N turns of 2π to get back to the point were one started. The phase factors behave as a phase of a spinning particle having effective fractional spin $1/N$. I have proposed this kind of mechanism as an explanation of so called hydrino atoms claimed to have the spectrum of hydrogen atom but with energies scaled up by N^2 [K103] , [D8]. The first guess that N corresponds to m in $\nu = 1/m$ is wrong. Rather, N corresponds to N in $\nu = N/m$ which means many-valued Laughlin wave functions in single branched space-time.

Similar argument applies also in CP_2 degrees of freedom. Only the N-multiples of 2π rotations by CP_2 isometries corresponding to color hyper charge and color iso-spin would affect trivially the point of multi-branched surface. Since the contribution of Kähler charge to electromagnetic

charge corresponds also to anomalous hyper-charge of spinor field in question, an additional geometric contribution to the anomalous hypercharge would mean anomalous electromagnetic charge.

It must be emphasized the fractionization of the isometry charges is only effective and results from the interpretation of isometries as space-time transformations rather than transformation rotating entire space-time sheet in embedding space. Also classical charges are effectively fractionized in the sense that single branch gives in a symmetric situation a fraction of $1/n$ of the entire charge. Later it will be found that also a genuine fractionization occurs and is due to the classical topologized Kähler charge of the anyon track.

2. Modelling anyons in terms of gauge group and isometry group

Anyons can be modelled in terms of the gauge symmetry breaking $SU(2)_L \to H$, where H is discrete sub-group. The breaking of gauge symmetry results by the action of multi-valued gauge transformation $g(x)$ such that different branches of the multi-valued map are related by the action of H.

1. The standard description of anyons is based on spontaneous symmetry breaking of a gauge symmetry G to a discrete sub-group H dynamically [A26]. The gauge field has suffered multi-valued gauge transformation such that the elements of H permute the different branches of $g(x)$. The puncture is characterized by the element of the H associated with the loop surrounding puncture. In the idealized situation that gauge field vanishes, the parallel translation of a particle around puncture affects the particle state, itself a representation of G, by the element of the homotopy $\pi_1(G/H) = H$ identifiable as non-Abelian magnetic charge. Thus holonomy group corresponds to homotopy group of G/H which in turn equals to H. This in turn implies that the infinite-dimensional braid group whose elements define holonomies in turn is represented in H.

2. In TGD framework the multi-valuedness of $g(x)$ corresponds to a many-branched character of 4-surface. This in turn induces a branching of both magnetic flux tube and anyon tracks describable in terms of $H \subset SU(2)_L$ acting as an isotropy group for the boundaries of the magnetic flux tubes. H can correspond only to a non-Abelian subgroup $SU(2)_L$ of the electro-weak gauge group for the induced (classical) electro-weak gauge fields since the Chern-Simons action associated with the classical color gauge fields vanishes identically. The electro-weak holonomy group would reduce to a discrete group H around loops defined by anyonic flux tubes surrounding magnetic field lines inside the magnetic flux tubes containing anyons. The reduction to H need to occur only at the boundaries of the space-time sheet where conducting anyons would reside: boundaries indeed correspond to asymptotia in well-defined sense. Electro-weak symmetry group can be regarded as a sub-group of color group of isometries in a well-defined sense so that H can be regarded also as a subgroup of color group acting as isotropies of the multi-branched surface at least in the in regions where gauge field vanishes.

3. For branched surfaces the points obtained by moving around the puncture correspond in a good approximation to some elements of $h \in H$ leading to a new branch but the 2-surface as a whole however remains invariant. The braid group of the punctured 2-surface would be also now represented as transformations of H. The simplest situation is obtained when H is a cyclic group Z_N of the $U(1)$ group of CP_2 geodesic in such a way that 2π rotation around symmetry axis corresponds to the generating element $exp(i2\pi/N)$ of Z_N.

   Dihedral group D_n having order $2n$ and acting as symmetries of n-polygon of the plane is especially interesting candidate for H. For $n = 2$ the group is Abelian group $Z_2 \times Z_2$ whereas for $n > 2$ D_n is a non-Abelian sub-group of the permutation group S_n. The cyclic group Z_4 crucial for TQC is a sub-group of D_4 acting as symmetries of square. D_4 has a 2-dimensional faithful representation. The numbers of elements for the conjugacy classes are 1, 1, 2, 2, 2. The sub-group commuting with a fixed element of a conjugacy class is D_4 for the 1-element conjugacy classes and cyclic group Z_4 for 2-element conjugacy classes. Hence 2-valued magnetic flux would be accompanied by Z_4 valued "electric charge" identifiable as a cyclic group permuting the branches.

3. Can one understand the increase in conductivity and filling fractions at plateaus?

Quantum Hall effect involves the increase of longitudinal conductivity by a factor of order 10^{13} [D16]. The reduction of dissipation could be understood as being caused by the fact that anyonic electrons are closed inside the magnetic flux tubes representing their tracks so that their interactions with matter and thus also dissipation are reduced.

Laughlin's theory [D16, D13] gives almost universal description of many aspects of quantum Hall effect and the question arises whether Laughlin's wave functions are defined on possibly multi-branched space-time sheet X^4 or at projection of X^4 to M^4_+. Since most theoreticians that I know still live in single sheeted space-time, one can start with the most conservative assumption that they are defined at the projection to M^4_+. The wave functions of one-electron state giving rise filling fraction $\nu = 1/m$ are constructed of $(z_i - z_j)^m$, where m is odd by Fermi statistics.

Also rational filling fractions of form $\nu = 1/m = N/n$ have been observed. These could relate to the presence of states whose projections to M^4 are multi-valued and which thus do not have any "classical" counterpart. For N-branched surface the single-valued wave functions $(\xi_i - \xi_j)^n$, n odd by Fermi statistics, correspond to apparently multi-valued wave functions $(z_i - z_j)^{n/N}$ at M^4 projection with fractional relative angular momenta $m = n/N$. The filling fraction would be $\nu = N/n$, n odd. All filling fractions reported in [D16] have n odd with n varying in the range $1 - 7$. N has the values $1, 2, 3, 4, 5, 7, 9$. Also values $N = 12, 13$ for which $n = 5$ are reported [B24].

The filling fractions $\nu = N/n = 5/2, 3/8, 3/10$ reported in [D17] would require even values of n conflicting with Fermi statistics. Obviously Lauhglin's model fails in this case and the question is whether one these fractions could correspond to bosonic anyons, perhaps Cooper pairs of electrons inside track flux tubes. The Z_N valued charge associated with N-branched surfaces indeed allows the maximum $2N$ electrons per anyon. Bosonic anyons are indeed the building block of the TQC model of [B24]. The anyon Cooper pairs could be this kind of states and their BE condensation would make possible genuine super-conductivity rather than only exceptionally high value of conductivity.

One can imagine also more complex multi-electron wave functions than those of Laughlin. The so called conformal blocks representing correlation functions of conformal quantum field theories are natural candidates for the wave functions [D12] and they appear naturally as state functions of in topological quantum field theories. For instance, wave functions which are products of factors $(z^k - z^l)^2$ with the Pfaffian $Pf(A_{kl})$ of the matrix $A_{kl} = 1/(z_k - z_l)$ guaranteeing anti-symmetrization have been used to explain even values of m [D12].

4. N-branched space-time surfaces make possible Z_N valued topological charge

According to [D12] that $2n$ non-Abelian anyon pairs with charge $1/4$ created from vacuum gives rise to a 2^{n-1}-fold degenerate ground state. It is also argued that filling fraction $5/2$ could correspond to this charge [B24]. TGD suggests somewhat different interpretation. 4-fold branching implies automatically the Z_4-valued topological charge crucial for anyonic quantum computation. For 4-branched space-time surface the contribution of a single branch to electron's charge is indeed $1/4$ units but this has nothing to do with the actual charge fractionization. The value of ν is of form $\nu = /m$ and electromagnetic charge equals to $\nu = 4e/m$ in this kind of situation.

If anyons (electron plus flux tube representing its track) have Z_4 charges 1 and 3, their Cooper pairs have charges 0 and 2. The double-fold degeneracy for anyon's topological charge means that it possesses topological spin conserved modulo 4. In presence of $2n$ anyon pairs one would expect 2^n-fold degeneracy. The requirement that the net topological charge vanishes modulo 4 however fixes the topological charge of n: th pair so that 2^{n-1} fold degeneracy results.

A possible interpretation for Z_N-valued topological charge is as fractional angular momenta k/N associated with the phases $exp(ik2\pi/N)$, $k = 0, 1, ..., n - 1$ of particles in multi-branched surfaces. The projections of these wave functions to single-branched space-time would be many-valued. If electro-weak gauge group breaks down to a discrete subgroup H for magnetic flux tubes carrying anyonic "tracks", this symmetry breakdown could induce their multi-branched property in the sense rotation by 2π would correspond to H isometry leading to a different branch.

Topologization of Kähler charge as an explanation for charge fractionization

The argument based on what happens when one adds one anyon to the anyon system by utilizing Faraday's law [D16] leads to the conclusion that anyon charge is fractional and given by νe. The

anyonic flux tube along boundary of the flux tube corresponds to the left hand side in the Faraday's equation

$$\oint E \cdot dl = -\frac{d\Phi}{dt} \ .$$

By expressing E in turns of current using transversal conductivity and integrating with respect to time, one obtains

$$Q = \nu e$$

for the charge associated with a single anyon. Hence the addition of the anyon means an addition of a fractional charge νe to the system. This argument should survive as such the 1-branched situation so that at least in this case the fractional charges should be real.

In N-branched case the closed loop $\oint E \cdot dl$ around magnetic flux tube corresponds to N-branched anyon and surrounds the magnetic flux tube N times. This would suggest so that net magnetic flux should be N times the one associated with single but unclosed 2π rotation. Hence the formula would seem to hold true as such also now for the total charge of the anyon and the conclusion is that charge fractionization is real and cannot be an effective effect due to fractionization of charge at single branch of anyon flux tube.

One of the basic differences between TGD and Maxwell's theory is the possibility of vacuum charges and this provides an explanation of the effect is in terms of vacuum Kähler charge. Kähler charge contributes $e/2$ to the charge of electron. Anyon flux tube can generate vacuum Kähler charge changing the net charge of the anyon. If the anyon charge equals to νe the conclusions are following.

1. The vacuum Kähler charge of the anyon track is $q = (\nu - 1)e$.

2. The dimension of the CP_2 projection of the anyon flux tube must be $D = 3$ since only in this case the topologization of anyon charge becomes possible so that the charge density is proportional to the Chern-Simons term $A \wedge dA/4\pi$. Anyon flux tubes cannot be superconducting in the sense that non-integrable phase factor $exp(\int A \cdot dl)$ would define global order parameter. The boundaries of anyonic flux tubes could however remain potentially superconducting and anyon Cooper pairs would be expelled there by Meissner effect. This gives super-conductivity in length scale of single flux tube. Conductivity and super-conductivity in long length scales requires that magnetic flux tubes are glued together along their boundaries partially.

3. By Bohr quantization anyon tracks can have $r_n = \sqrt{n} \times r_B$, $n \leq m$, where r_m corresponds to the radius of the magnetic flux tube carrying m flux quanta. Only the tracks with radius r_m contribute to boundary conductivity and super-conductivity giving $\nu = 1/m$ for singly branched surfaces.

   The states with $\nu = N/m$ cannot correspond to non-super-conducting anyonic tracks with radii r_n, $n < m$, n odd, since these cannot contribute to boundary conductivity. The many-branched character however allows an N-fold degeneracy corresponding to the fractional angular momentum states $exp(ik\phi/N)$, $k = 0, ..., N-1$ of electron inside anyon flux tubes of radius r_m. k is obviously a an excellent candidate for the Z_N-valued topological charge crucial for anyonic quantum computation. Z_4 is uniquely selected by the braid matrix R.

   Only part of the anyonic Fermi sea need to be filled so that filling fractions $\nu = k/m$, $k = 1, ..., N$ are possible. Charges νe are possible if each electron inside anyon track contributes $1/m$ units to the fractional vacuum Kähler charge. This is achieved if the radius of the anyonic flux tube grows as $\sqrt{k/m}$ when electrons are added. The anyon tracks containing several electrons give rise to composite fermions with fermion number up to $2N$ if both directions of electron spin are allowed.

4. Charge fractionization requires vacuum Kähler charge has rational values $Q_K = (\nu - 1)e$. The quantization indeed occurs for the helicity defined by Chern-Simons term $A \wedge dA/4\pi$. For compact 3-spaces without boundary the helicity can be interpreted as an integer valued invariant characterizing the linking of two disjoint closed curves defined by the magnetic field

lines. This topological charge can be also related to the asymptotic Hopf invariant proposed by Arnold [B48], which in non-compact case has a continuum of values. Vacuum Kähler current is obtained from the topological current $A \wedge dA/4\pi$ by multiplying it with a function of CP_2 coordinates completely fixed by the field equations. There are thus reasons to expect that vacuum Kähler charge and also the topological charges obtained by multiplying Chern Simons current by $SU(3)$ Hamiltonians are quantized for compact 3-surfaces but that the presence of boundaries replaces integers by rationals.

What happens in quantum Hall system when the strength of the external magnetic field is increased?

The proposed mechanism of anyonic conductivity allows to understand what occurs in quantum Hall system when the intensity of the magnetic field is gradually increased.

1. Percolation picture encourages to think that magnetic flux tubes fuse partially along their boundaries in a transition to anyon conductivity so that the anyonic states localized at the boundaries of flux tubes become de-localized much like electrons in metals. Laughlin's states provide an idealized description for these states. Also anyons, whose tracks have Bohr radii r_m smaller than the radius r_B of the magnetic flux tube could be present but they would not participate in this localization. Clearly, the anyons at the boundaries of magnetic flux tubes are highly analogous to valence electrons in atomic physics.

2. As the intensity of the magnetic field B increases, the areas a of the flux tubes decreases as $a \propto 1/B$: this means that the existing contacts between neighboring flux tubes tend to be destroyed so that anyon conductivity is reduced. On the other hand, new magnetic flux tubes must emerge by the constancy of the average magnetic flux implying $dn/da \propto B$ for the average density of flux tubes. This increases the probability that the newly generated flux tubes can partially fuse with the existing flux tubes.

3. If the flux tubes are not completely free to move and change their shape by area preserving transformations, one can imagine that for certain value ranges of B the generation of new magnetic flux tubes is not favored since there is simply no room for the newcomers. The Fermi statistics of the anyonic electrons at the boundaries of flux tubes might relate to this non-hospitable behavior. At certain critical values of the magnetic field the sizes of flux tubes become however so small that the situation changes and the new flux tubes penetrate the system and via the partial fusion with the existing flux tubes increase dramatically the conductivity.

Also protonic anyons are possible

According to the TGD based model, any charged particle can form anyons and the strength of the magnetic field does not seem to be crucial for the occurrence of the effect and it could occur even in the Earth's magnetic field. The change of the cyclotron and Larmor frequencies of the charged particle in an external magnetic field to a value corresponding to the fractional charge provides a clear experimental signature for both the presence of anyons and for their the fractional charge.

Interestingly, water displays a strange scaling of proton's cyclotron frequency in an external magnetic field [D14] , [J40]. In an alternating magnetic field of.1551 Gauss (Eearth's field has a nominal value of.58 Gauss) a strong absorption at frequency $f = 156$ Hz was observed. The frequency was halved when D_2O was used and varied linearly with the field strength. The resonance frequency however deviated from proton's Larmor frequency, which suggests that a protonic anyon is in question. The Larmor frequency would be in this case $f_L = r \times \nu eB/2m_p$, where $r = \mu_p/\mu_B = 2.2792743$ is the ratio of proton's actual magnetic moment to its value for a point like proton. The experimental data gives $\nu = .6003 = 3/5$ with the accuracy of 5×10^{-4} so that 3-branched protonic anyons with $m = 5$ would be responsible for the effect.

If this interpretation is correct, entire p-adic hierarchy of anyonic NMR spectroscopies associated with various atomic nuclei would become possible. Bosonic anyon atoms and Cooper pairs of fermionic anyon atom could also form macroscopic quantum phases making possible superconductivity very sensitive to the value of the average magnetic field and bio-systems and brain could utilize this feature.

3.4.3 Does The Quantization Of Planck Constant Transform Integer Quantum Hall Effect To Fractional Quantum Hall Effect?

The model for topological quantum computation inspired the idea that Planck constant might be dynamical and quantized. The work of Nottale [E1] gave a strong boost to concrete development of the idea and it took year and half to end up with a proposal about how basic quantum TGD could allow quantization Planck constant associated with M^4 and CP_2 degrees of freedom such that the scaling factor of the metric in M^4 degrees of freedom corresponds to the scaling of $\hbar$ in CP_2 degrees of freedom and vice versa [K38]. The dynamical character of the scaling factors of M^4 and CP_2 metrics makes sense if space-time and embedding space, and in fact the entire quantum TGD, emerge from a local version of an infinite-dimensional Clifford algebra existing only in dimension $D = 8$ [K110].

The predicted scaling factors of Planck constant correspond to the integers n defining the quantum phases $q = exp(i\pi/n)$ characterizing Jones inclusions. A more precise characterization of Jones inclusion is in terms of group $G_b \subset SU(2) \subset SU(3)$ in CP_2 degrees of freedom and $G_a \subset SL(2,C)$ in M^4 degrees of freedom. In quantum group phase space-time surfaces have exact symmetry such that to a given point of M^4 corresponds an entire G_b orbit of CP_2 points and vice versa. Thus space-time sheet becomes $N(G_a)$ fold covering of CP_2 and $N(G_b)$-fold covering of M^4. This allows an elegant topological interpretation for the fractionization of quantum numbers. The integer n corresponds to the order of maximal cyclic subgroup of G.

In the scaling $\hbar_0 \to n\hbar_0$ of M^4 Planck constant fine structure constant would scale as

$$\alpha = \frac{e^2}{4\pi\hbar c} \to \frac{\alpha}{n} \ ,$$

and the formula for Hall conductance would transform to

$$\sigma_H \to \frac{\nu}{n}\alpha \ .$$

Fractional quantum Hall effect would be integer quantum Hall effect but with scaled down α. The apparent fractional filling fraction $\nu = m/n$ would directly code the quantum phase $q = exp(i\pi/n)$ in the case that m obtains all possible values. A complete classification for possible phase transitions yielding fractional quantum Hall effect in terms of finite subgroups $G \subset SU(2) \subset SU(3)$ given by ADE diagrams would emerge (A_n, D_{2n}, E_6 and E_8 are possible). What would be also nice that CP_2 would make itself directly manifest at the level of condensed matter physics.

3.4.4 Why 2+1-Dimensional Conformally Invariant Witten-Chern-Simons Theory Should Work For Anyons?

Wess-Zumino-Witten theories are 2-dimensional conformally invariant quantum field theories with dynamical variables in some group G. The action contains the usual 2-dimensional kinetic term for group variables allowing conformal group action as a dynamical symmetry plus winding number defined associated with the mapping of 3-surface to G which is $Diff^4$ invariant. The coefficient of this term is quantized to integer.

If one couples this theory to a gauge potential, the original chiral field can be transformed away and only a Chern-Simons term defined for the 3-manifold having the 2-dimensional space as boundary remains. Also the coefficient k of Chern-Simons term is quantized to integer. Chern-Simons-Witten action has close connection with Wess-Zumino-Witten theory. In particular, the states of the topological quantum field theory are in one-one correspondence with highest weights of the WZW action.

The appearance of 2+1-dimensional $Diff^3$ invariant action can be understood from the fundamentals of TGD.

1. Light-like 3-surfaces of both future light-cone M^4_+ and of space-time surface X^4 itself are in a key role in the construction of quantum TGD since they define causal determinants for Kähler action.

2. At the space-time level both the boundaries of X^4 and elementary particle horizons surrounding the orbits of wormhole contacts define light-like 3-surfaces. The field equations are

satisfied identically at light-like boundaries. Of course, the projections of the the light-like surfaces of X^4 to Minkowski space need not look light-like at all, and even boundaries of magnetic flux tubes could be light-like.

Light-like 3-surfaces are metrically 2-dimensional and allow a generalized conformal invariance crucial for the construction of quantum TGD. At the level of embedding space conformal super-symplectic invariance results. At the space-time level the outcome is conformal invariance highly analogous to the Kac Moody symmetry of super string models [K27, K96]. In fact, there are good reasons to believe that the three-dimensional Chern-Simons action appears even in the construction of configuration space metric and give an additional contribution to the configuration space metric when the light-like boundaries of 3-surface have 3-dimensional CP_2 projection.

3. By the effective two-dimensionality the Wess-Zumino-Witten action containing Chern-Simons term is an excellent candidate for the quantum description of S-matrix associated with the light-like 3-surfaces since by the vanishing of the metric determinant one cannot define any general coordinate invariant 3-dimensional action other than Chern-Simons action. The boundaries of the braid formed by the magnetic flux tubes having light-like boundaries, perhaps having flux tubes between swapped flux tubes would define the 2+1-dimensional space-time associated with a braid, would define the arena of Witten-Chern-Simons theory describing anyons. This S-matrix can be interpreted also as characterizing either a 3-dimensional quantum state since light-like boundaries are limiting cases of space-like 3-surfaces.

4. Kähler action defines an Abelian Chern-Simons term and the induced electroweak gauge fields define a non-Abelian variant of this term. The Chern-Simons action associated with the classical color degrees of freedom vanishes as is easy to find. The classical color fields are identified as projections of Killing vector fields of color group: $A^c_\alpha = j^A_k \partial_\alpha s^k \tau_A = J_k{}^r \partial_r H^A \partial_\alpha s^k$. The classical color gauge field is proportional to the induced Kähler form: $F^c_{\alpha\beta} = H^A J_{\alpha\beta} \tau_A$. A little calculation shows that the instanton density vanishes by the identity $H_A H^A = 1$ (this identity is forced by the necessary color-singletness of the YM action density and is easy to check in the simpler case of S^2.

5. Since qubit realizes the fundamental representation of the quantum group $SU(2)_q$, $SU(2)$ is in a unique role concerning the construction of modular functors and quantum computation using Chern-Simons action. The quantum group corresponding to $q = exp(i2\pi/r)$, $r = 5$ is realized for the level $k = 3$ Chern-Simons action and satisfies the constraint $r = k + c_g$, where $c_g = 2$ is the so called dual Coxeter number of $SU(2)$ [B24, B29, B40].

   The exponent non-Abelian $SU(2)_L \times U(1)$ Chern-Simons action combined with the corresponding action for Kähler form so that effective reduction to $SU(2)_L$ occurs, could appear as a multiplicative factor of the WCW spinor fields defined in the WCW . Since 3-dimensional quantum state would represent a 2-dimensional time evolution the role of these phase factor would be very analogous to the role of ordinary Chern-Simons action.

3.5 Topological Quantum Computation In TGD Universe

The general philosophy behind TQC inspires the dream that the existence of basic gates, in particular the maximally entangling 2-gate R, is guaranteed by the laws of Nature so that no fine tuning would be needed to build the gates. Negentropy Maximization Principle, originally developed in context of TGD inspired theory of consciousness, is a natural candidate for this kind of Law of Nature.

3.5.1 Concrete Realization Of Quantum Gates

The bold dream is that besides 2-gates also 1-gates are realized by the basic laws of Nature. The topological realization of the 3-braid representation in terms of Temperley-Lie algebra allows the reduction of 1-gates to 2-gates.

NMP and TQC

Quantum jump involves a cascade of self measurements in which the system under consideration can be though of as decomposing to two parts which are either un-entangled or possess rational or extended rational entanglement in the final state. The sub-system is selected by the requirement that entanglement negentropy gain is maximal in the measurement of the density matrix characterizing the entanglement of the sub-system with its complement.

In the case case that the density matrix before the self measurement decomposes into a direct sum of matrices of dimensions N_i, such that $N_i > 1$ holds true for some values of i, say i_0, the final state is a rationally entangled and thus a bound state. i_0 is fixed by the requirement that the number theoretic entropy for the final state maximally negative and equals to $klog(p)$, where p^k is the largest power of prime dividing N_{i_0}. This means that maximally entangled state results and the density matrix is proportional to a unit matrix as it is also for the entanglement produced by R. In case of R the density matrix is $1/2$ times 2-dimensional unit matrix so that bound state entanglement negentropy is 1 bit.

The question is what occurs if the density matrix contains a part for which entanglement probabilities are extended rational but not identical. In this case the entanglement negentropy is positive and one could argue that no self-measurement occurs for this state and it remains entangled. If so then the measurement of the density matrix would occur only when it increases entanglement negentropy. This looks the only sensible option since otherwise only bound state entanglement with identical entanglement probabilities would be possible. This question is relevant also because Temperley-Lieb representation using $(AA)-A-A$ system involves entanglement with entanglement probabilities which are not identical.

In the case that the 2-gate itself is not directly entangling as in case of R' and R'', NMP should select just the quantum history, that single particle gates at it guarantee maximum entanglement negentropy. Thus NMP would come in rescue and give hopes that various gates are realized by Nature.

Non-Abelian anyon systems are modelled in terms of punctures of plane and Chern-Simons action for the incompressible vector potential of hydrodynamical flow. It is interesting to find how these ideas relate to the TGD description.

Non-Abelian anyons reside at boundaries of magnetic flux tubes in TGD

In [B24] anyons are modelled in terms of punctures of plane defined by the slab carrying Hall current. In TGD the punctures correspond naturally to magnetic flux tubes defining the braid. It is now however obvious under what conditions the braid containing the TGD counterpart of (AA)-A-A system can be described as a punctured disk if the flux tubes describing the tracks of valence anyons are very near to the boundaries of the magnetic flux tubes. Rather, the punctured disk is replaced with the closed boundary of the magnetic flux tube or of the structure formed by the partial fusion of several magnetic flux tubes. This microscopic description and is consistent with Laughlin's model only if it is understood as a long length scale description.

Non-Abelian charges require singularities and punctures but a two-surface which is boundary does not allow punctures. The punctures assigned with an anyon pair would become narrow wormhole threads traversing through the interior of the magnetic flux tube and connecting the punctures like wormholes connect two points of an apple. It is also possible that the threads connect the surfaces of two nearby magnetic flux tubes. The wormhole like character conforms with the fact that non-Abelian anyons appear always in pairs.

The case in which which the ends of the wormhole thread belong to different neighboring magnetic flux tubes, call them T_1 and T_2, is especially interesting as far as the model for TQC is considered. The state of $(AA)-A-A$ system before (after) the 3-braid operation would be identifiable as anyons near the surface of T_1 (T_2). If only sufficiently local operations are allowed, the braid group would be same as for anyons inside disk. This means consistency with the anyon model of [B24] for TQC requiring that the dimension for the space of ground states is 2^{n-1} in a system consisting of n anyon pairs.

The possibility of negative energies allows inspires the idea that the anyons at T_2 have negative energies so that the anyon system would have a vanishing net energy. This would conform with the idea that the scattering from initial to final state is equivalent with the creation of zero

energy state for which initial (final) state particles have positive (negative) energies, and with the fact that the boundaries of magnetic flux tubes are light-like systems for which 3-D quantum state is representation for a 2-D time evolution.

Since the correlation between anyons at the ends of the wormhole thread is purely topological, the most plausible option is that they behave as free anyons dynamically. Assuming 4-branched anyon surfaces, the charges of anyons would be of form $Q = \nu_A e$, $\nu_A = 4/m$, m odd.

Consider now the representation of 3-braid group. That the mapping class group for the 3-braid system should have a 2-dimensional representation is obvious from the fact that the group has same generators as the mapping class group for torus which is represented by as $SL(2, Z)$ matrices acting on the homology of torus having two generators a, b corresponding to the two non-contractible circles around torus. 3-braid group would be necessarily represented in Temperley-Lieb representation.

The character of the anyon bound state is important for braid representations.

1. If anyons form loosely bound states (AA), the electrons are at different tracks and the charge is additive in the process so that one has $Q_{AA} = 2Q_A = 8/m$, m odd, which is at odds with statistics. It might be that the naïve rule of assigning fractional charge to the state does not hold true for loosely bound bosonic anyons. In this case $(AA) - A$ system with charge states $((1, -1), 1)$ and $((1, 1), -1)$ would be enough for realizing 1-gates in TQC. The braid operation s_2 of Temperley-Lieb representation represented $(A_1A_2) - A_3 \to (A_1A_3) - A_2$ would correspond to an exchange of the dance partner by a temporary decay of (A_1A_2) followed by a recombination to a quantum superposition of (A_1A_2) and (A_1A_3) and could be regarded as an ordinary braid operation rather than monodromy. The relative phase 1-gate would correspond to s_1 represented as braid operation for A_1 and A_2 inside (A_1A_2).

2. If anyons form tightly bound states (AA) in the sense that single anyonic flux tube carries two electrons, charge need not be additive so that bound states could have charges $Q = 4/2m_1$ so that the vacuum Kähler charge $Q_K = 4(1/m_1 - 2/m)$ would be created in the process. This would stabilize (AA) state and would mean that the braid operation $(A_1A_2) - A_3 \to (A_1A_3) - A_2$ cannot occur via a temporary decay to free anyons and it might be necessary to replace 3-braid group by a partially colored 3-braid group for $(AA) - A - A$ system which is sub-group of 3-braid group and has generators s_1^2 (two swaps for $(AA) - A$) and s_2 (swap for $A - A$) instead of s_1 and s_2. Also in this case a microscopic mechanism changing the value of (AA) Z^4 charge is needed and the situation might reduce to the case a) after all.

   The Temperley Lieb representation for this group is obtained by simply taking square of the generator inducing entanglement (s_2 rather than s_1 in the notation used!). The topological charge assignments for $(AA) - A - A$ system are $((1, -1), 1, -1)$ and $((1, 1), -1, -1)$. s_1^2 would correspond to the group element generating $(AA) - A$ entanglement and s_2 acting on $A - A$ pair would correspond to phase generating group element.

Braid representations and 4-branched anyon surfaces

Some comments about braid representations in relation to Z_N- valued topological charges are in order.

1. Yang-Baxter braid representation using the maximally entangling braid matrix R is especially attractive option. For anyonic computation with Z_4-valued topological charge R is the unique 2-gate conserving the net topological charge (note that the mixing of the $|1, 1\rangle$ and $|-1, -1\rangle$ is allowed). On the other, R allows only the conservation of Z_4 value topological charge. This suggests that the entanglement between logical qubits represented by $(AA) - A - A$ batches is is generated by R. The physical implication is that only $\nu = 4/n$ 4-branched anyons could be used for TQC.

2. In TGD framework the entangling braid representation inside batches responsible for 1-gates need not be the same since batches correspond to magnetic flux tubes. In standard physics context it would be harder to defend this kind of assumption. As will be found 3-braid Temperley-Lieb representation is very natural for 1-gates. The implication is that the n-braid system with braids represented as 4-batches would have 2^n-dimensional space of logical qubits in fact identical with the space of realizable qubits.

3. Also n-braid Temperley-Lieb representations are possible and the explicit expressions of the braiding matrices for 6-braid case suggest that Z_4 topological charge is conserved also now [B29]. In this case the dimension of the space of logical qubits is for highly favored value of quantum group parameter $q = exp(i\pi/5)$ given by the Fibonacci number $F(n)$ for n-braid case and behaves as Φ^{4n} asymptotically so that this option would be more effective. From $\Phi^4 = 1 + 3\Phi \simeq 8.03$ one can say that single 4-batch carries 3 bits of information instead of one. This is as it must be since topological charge is not conserved inside batches separately for this option.

4. $(AA) - A$ representation based on Z_4-valued topological charge is unique in that the space of logical qubits would be the space of topologically realizable qubits. Quantum superposition of logical qubits could could be represented $(AA) - A$ entangled state of form $a|2, -1\rangle + b|0, 1\rangle$ generated by braid action. Relative phase could be generated by braid operation acting on the entangled state of anyons of (AA) Cooper pair. Since the superposition of logical cubits corresponds to an entangled state $a|2, -1\rangle + b|0, 1\rangle$ for which coefficients are extended rational numbers, the number theoretic realization of the bound state property could pose severe conditions on possible relative phases.

3.5.2 Temperley-Lieb Representations

The articles of Kaufmann [B37] and Freedman [B29, B41] provide enjoyable introduction to braid groups and to Tempeley-Lie representations. In the sequel Temperley-Lieb representations are discussed from TGD view point.

Temperley-Lieb representation for 3-braid group

In [B37] it is explained how the so called Temperley-Lie algebra defined by 2×2-matrices I, U_1, U_2 satisfying the relations $U_1^2 = dU_1$, $U_2^2 = dU_2$, $U_1U_2U_1 = U_2$, $U_2U_1U_2 = U_1$ allows a unitary representation of Artin's braid group by unitary 2×2 matrices. The explicit representations of the matrices U_1 and U_2 (note that U_i/d acts as a projector) given by

$$\begin{aligned} U_1 &= \begin{pmatrix} d & 0 \\ 0 & 0 \end{pmatrix} , \\ U_2 &= \begin{pmatrix} \frac{1}{d} & \sqrt{1-\frac{1}{d^2}} \\ \sqrt{1-\frac{1}{d^2}} & d-\frac{1}{d} \end{pmatrix} . \end{aligned} \tag{3.5.1}$$

Note that the eigenvalues of U_i are d and 0. The representation of the elements s_1 and s_2 of the 3-braid group is given by

$$\begin{aligned} \Phi(s_1) &= AI + A^{-1}U_1 = \begin{pmatrix} -U^{-3} & 0 \\ 0 & U \end{pmatrix} , \\ \Phi(s_2) &= AI + A^{-1}U_2 = \begin{pmatrix} -\frac{U^3}{d} & \frac{U^{-1}}{\sqrt{1-(1/d)^2}} \\ \frac{U^{-1}}{\sqrt{1-(1/d)^2}} & \frac{U^{-5}}{d} \end{pmatrix} , \\ U &= exp(i\phi) . \end{aligned} \tag{3.5.2}$$

Here the condition $d = -A^2 - A^{-2}$ is satisfied. For $A = exp(i\phi)$, with $|\phi| \leq \pi/6$ or $|\pi - \phi| \leq \pi/6$, the representation is unitary. The constraint comes from the requirement $d > 1$. From the basic representation it follows that the eigenvalues of $\Phi(s_i)$ are $-exp(-3i\phi)$ and $exp(i\phi)$.

Tihs 3-braid representation is a special case of a more general Temperley-Lieb-Jones representation discussed in [B29] using notations $A = \sqrt{-1}exp(-i2\pi/4r)$, $s = A^2$, and $q = A^4$. In this case all eigen-values of all representation matrices are -1 and $q = exp(-i2\pi/r)$. This representation results by multiplying Temperley-Lieb representation above with an over-all phase factor $exp(4i\phi)$ and by the replacement $A = exp(i\phi) \to \sqrt{-1}A$.

Constraints on the parameters of Temperley-Lieb representation

The basic mathematical requirement is that besides entangling 2-gate there is minimum set of 1-gates generating infinite sub-group of $U(2)$. Further conditions come from the requirement that a braid representation is in question. In the proposal of [B24, B29] the 1-gates are realized using Temperley-Lieb 3-braid representation. It is found that there are strong constraints to the representation and that relative phase gate generating the phase $exp(i\phi) = exp(i2\pi/5)$ is the simplest solution to the constraints.

The motivation comes from the findings made already by Witten in his pioneering work related to the topological quantum field theories and one can find a good representation about what is involve din [A29].

Topological quantum field theories can produce unitary modular functors when the $A = q^{1/4} = exp(i\phi)$ characterizing the quantum group multiplication is a root of unity so that the quantum enveloping algebra $U(Sl(2))_q$ defined as the quantum version of the enveloping algebra $U(Sl(2))$ is not homomorphic with $U(Sl(2))$ and theory does not trivialize. Besides this, q must satisfy some consistency conditions. First of all, $A^{4n} = 1$ must be satisfied for some value of n so that A is either a primitive l: th, $2l$: th of unity for l odd, or $4l$: th primitive root of unity.

This condition relates directly to the fact that the quantum integers $[n]_q = (A^{2n} - A^{-2n})/(A^2 - A^{-2})$ vanish for $n \geq l$ so that the representations for a highest weight n larger than l are not irreducible. This implies that the theory simplifies dramatically since these representations can be truncated away but can cause also additional difficulties in the definition of link invariants. Indeed, as Witten found in his original construction, the topological field theories are unitary for $U(Sl(2))_q$ only for $A = exp(ik\pi/2l)$, k not dividing $2l$, and $A = exp(i\pi/l)$, l odd (no multiples are allowed) [A29]. $n = 2l = 10$, which is the physically favored choice, corresponds to the relative phase $4\phi = 2\pi/5$.

Golden Mean and quantum computation

Temperley-Lieb representation based on $q = exp(i2\pi/5)$ is highly preferred physically.

1. One might hope that the Yang-Baxter representation based on maximally entangling braid matrix R might work. $R^8 = 1$ constraint is however not consistent with Temperley-Lieb representations. The reason is that $\Phi^8(s_1) = 1$ gives $\phi = \pi/4 > \pi/6$ so that unitarity constraint is not satisfied. $\phi = exp(i2\pi/16)$ corresponding $r = 4$ and to the matrix $\Phi(s_2) = \hat{R} = exp(i2\pi/16) \times R$ allows to satisfy the unitarity constraint. This would look like a very natural looking selection since $\Phi(s_2)$ would act as a Hadamard gate and NMP would imply identical entanglement probabilities if a bound state results in a quantum jump. Unfortunately, s_1 and s_2 do not generate a dense subgroup of $U(2)$ in this case as shown in [B29].

2. $\phi = \pi/10$ corresponding to $r = 5$ and Golden Mean satisfies all constraints coming from quantum computation and knot theory. That is it spans a dense subgroup of $U(2)$, and allows the realization of modular functor defined by Witten-Chern-Simons $SU(2)$ action for $k = 3$, which is physically highly attractive since the condition

$$r = k + c_g(SU(2))$$

connecting r, k and the dual Coxeter number $c_g(SU(N)) = n$ in WCS theories is satisfied for $SU(2)$ in this case for $r = 5$ and $k = 3$.

$SU(2)$ would have interpretation as the left-handed electro-weak gauge group $SU(2)_L$ associated with classical electro-weak gauge fields. The symmetry breaking of $SU(2)_L$ down to a discrete subgroup of $SU(2)_L$ yielding anyons would relate naturally to this. The conservation of the topologized Kähler charge would correlate with the fact that there is no symmetry breaking in the classical $U(1)$ sector. $k = 3$ Chern-Simons theory is also known to share the same universality class as simple 4-body Hamiltonian [B24] (larger values of k would correspond to $k + 1$-body Hamiltonians).

3. Number theoretical vision about intentional systems suggests that the preferred relative phases are algebraic numbers or more generally numbers which belong to a finite-dimensional extension of p-adic numbers. The idea about p-adic cognitive evolution as a gradual generation of increasingly complex algebraic extensions of rationals allows to see the extension containing Golden Mean $\Phi = (1+\sqrt{5})/2$ as one of the simplest extensions. The relative phase $exp(i4\phi) = exp(i2\pi/5)$ is expressible in an extension containing $\sqrt{\Phi}$ and Φ: one has $cos(4\phi) = (\Phi - 1)/2$ and $sin(4\phi) = \sqrt{5\Phi}/2$.

The general number theoretical ideas about cognition support the view that Golden Mean is in a very special role in the number theoretical world order. This would be due to the fact that $log(\Phi)/\pi$ is a rational number. This hypothesis would explain scaling hierarchies based on powers of Golden Mean. One could argue that the geometry of the braid should reflect directly the value of the $A = exp(i2\phi)$. The angle increment per single DNA nucleotide is $\phi/2 = 2\pi/10$ for DNA double strand (note that q would be $exp(i\pi/10)$, which raises the question whether DNA might be a topological quantum computer.

Bratteli diagram for $n = 5$ case, Fibonacci numbers, and microtubuli

Finite-dimensional von Neumann algebras can be conveniently characterized in terms of Bratteli diagrams [A32]. For instance, the diagram a) of the figure **??** at the end of the chapter represents the inclusion $N \subset M$, where $N = M_2(C) \otimes C$, $M = M_6(C) \otimes M_3(C) \otimes C$. The diagram expresses the embeddings of elements $A \otimes x$ of $M_2(C) \otimes C$ to $M_6(C)$ as a tensor product $A_1 \otimes A_2 \otimes x$

$$\begin{aligned} A_1 &= \begin{pmatrix} A & . & . \\ . & A & . \\ . & . & A \end{pmatrix} , \\ A_2 &= \begin{pmatrix} A & . \\ . & x \end{pmatrix} . \end{aligned} \tag{3.5.3}$$

Bratteli diagrams of infinite-dimensional von Neumann algebras are obtained as limiting cases of finite-dimensional ones (see **Fig. 3.1**).

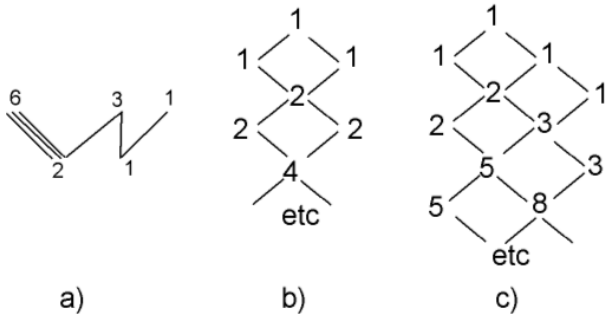

Figure 3.1: a) Illustration of Bratteli diagram. b) and c) give Bratteli diagrams for $n = 4$ and $n = 5$ Temperley Lieb algebras

2. Temperley Lieb algebras approximate II_1 factors

The hierarchy of inclusions of with $|M_{i+1} : M_i| = r$ defines a hierarchy of Temperley-Lieb algebras characterizable using Bratteli diagrams. The diagrams b) and c) of the figure **??** at the end of the chapter characterize the Bratteli diagrams for $n = 4$ and $n = 5$. For $n = 4$ the dimensions of algebras come in powers of 2 in accordance with the fact $r = 2$ is the dimension of the effective tensor factor of II_1.

For $n = 5$ and $B_m = \{1, e_1, ..., e_m\}$ the dimensions of the two tensor factors of the Temperley Lieb-representation are two subsequent Fibonacci numbers F_{m-1}, F_m ($F_{m+1} = F_m + F_{m-1}$, $F_1 = 1, F_2 = 1$) so that the dimension of the tensor product is $dim(B_m) = F_m F_{m-1}$. One has $dim(B_{m+1})/dim(B_m) = F_m/F_{m-2} \to \Phi^2 = 1 + \Phi$, the dimension of the effective tensor factor for the corresponding hierarchy of II_1 factors. Hence the two dimensional hierarchies "approximate" each other. In fact, this result holds completely generally.

The fact that r is approximated by an integer in braid representations is highly interesting from the point of view of TQC. For 3-braid representation the dimension of Temperley-Lieb representation is 2 for all values of n so that 3-braid representation defines single (topo)logical qubit as $(AA) - A - A$ realization indeed assumes. One could optimistically say that TGD based physics automatically realizes topological qubit in terms of 3-braid representation and the challenge is to understand the details of this realization.

2. Why Golden Mean should be favored?

The following argument suggests a physical reason for why just Golden Mean should be favored in the magnetic flux tube systems.

1. Arnold [B48] has shown that if Lorentz 3-force satisfies the condition $F_B = q(\nabla \times B) \times B = q\nabla\Phi$, then the field lines of the magnetic field lie on $\Phi = constant$ tori. On the other hand, the vanishing of the Lorentz 4-forces for solutions of field equations representing asymptotic self-organized states, which are the "survivors" selected by dissipation, equates magnetic force with the negative of the electric force expressible as qE, $E = -\nabla\Phi + \partial_t A$, which is gradient if the vector potential does not depend on time. Since the vector potential depends on three CP_2 coordinates only for $D = 3$, this seems to be the case.

2. The celebrated Kolmogorov-Arnold-Moser (KAM) theorem is about the stability of systems, whose orbits are on invariant tori characterized by the frequencies associated with the n independent harmonic oscillator like degrees of freedom. The theorem states that the tori for which the frequency ratios are rational are highly unstable against perturbations: this is due to resonance effects. The more "irrational" the frequencies are, the higher the stability of the orbits is, and the most stable situation corresponds to frequencies whose ratio is Golden Mean. In quantum context the frequencies for wave motion on torus would correspond to multiples $\omega_i = n2\pi/L_i$, L_i the circumference of torus. This poor man's argument would suggest that the ratio of the circumferences of the most stable magnetic tori should be given by Golden Mean in the most stable situation: perhaps one might talk about Golden Tori!

3. Golden Mean and microtubuli

What makes this observation so interesting is that Fibonacci numbers appear repeatedly in the geometry of living matter. For instance, micro-tubuli, which are speculated to be systems performing quantum computation, represent in their structure the hierarchy Fibonacci numbers $5, 8, 13$, which brings in mind the tensor product representation $5 \otimes 8$ of B_5 (5 braid strands!) and leads to ask whether this Temperley-Lieb representation could be somehow realized using microtubular geometry.

According to the arguments of [B24] the state of n anyons corresponds to 2^{n-1} topological degrees of freedom and code space corresponds to F_n-dimensional sub-space of this space. The two conformations of tubulin dimer define the standard candidate for qubit, and one could assume that the conformation correlates strongly with the underlying topological qubit. A sequence of 5 *resp.* 8 tubulin dimers would give 2^4 *resp.* 2^7-dimensional space with $F_5 = 5$- *resp.* $F_7 = 13$-dimensional code sub-space so that numbers come out nicely. The changes of tubulin dimer conformations would be induced by the braid groups B_4 and B_7. B_4 would be most naturally realized in terms of a unit of 5-dimers by regarding the 4 first tubulins as braided punctures and 5th tubulin as the passive puncture. B_7 would be realized in a similar manner using a unit of 8 tubulin dimers.

Flux tubes would connect the subsequent dimers along the helical 5-strand *resp.* 8-strand defined by the microtubule. Nearest neighbor swap for the flux tubes would induce the change of the tubulin conformation and induce also entanglement between neighboring conformations. A full 2π helical twist along microtubule would correspond to 13 basic steps and would define a natural TQC program module. In accordance with the interpretation of II_1 factor hierarchy, (magnetic or

electric) flux tubes could be assumed to correspond to $r = 2$ II_1 factor and thus carry 2-dimensional representations of $n = 5$ or $n = 4$ 3-braid group. These qubits could be realized as topological qubits using $(AA) - A$ system.

Topological entanglement as space-time correlate of quantum entanglement

Quantum-classical correspondence encourages to think that bound state formation is represented at the space-time level as a formation of join along boundaries bonds connecting the boundaries of 3-space sheets. In particular, the formation of entangled bound states would correspond to a topological entanglement for the flux tubes forming braids. The light-likeness of the boundaries of the bonds gives a further support for this identification. During macro-temporal quantum coherence a sequence of quantum jumps binds effectively to single quantum jump and subjective time effectively ceases to run. The light-likeness for the boundaries of bonds means that geometric time stops and is thus natural space-time correlate for the subjective experience during macro-temporal quantum coherence.

Also the work with TQC lends support for a a deep connection between quantum entanglement and topological entanglement in the sense that the knot invariants constructed using entangling 2-gate R can detect linking. Temperley-Lieb representation for 3-braids however suggests that topological entanglement allows also single qubit representations for with quantum entanglement plays no role. One can however wonder whether the entanglement might enter into the picture in some natural manner in the quantum computation of Temperley-Lieb representation. The idea is simple: perhaps the physics of $(AA) - A - A$ system forces single qubit representation through the simple fact that the state space reduces in 4-batch to single qubit by topological constraints.

For TQC the logical qubits correspond to entangled states of anyon Cooper pair (AA) and second anyon A so that the quantum superposition of qubits corresponds to an entangled state in general. Several arguments suggest that logical qubits would provide Temperley-Lieb representation in a natural manner.

1. The number of braids inside 4-anyon batch (or 3-anyon batch in case that (AA) can decay temporarily during braid operation) 3 so that by the universality this system allows to compute the unitary Temperley-Lieb braid representation. The space of logical qubits equals to the entire state space since the number of qubits represented by topological ground state degeneracy is 1 instead of the expected three since $2n$ anyon system gives rise to 2^{n-1}-fold vacuum degeneracy. The degeneracy is same even when two of the anyons fuse to anyon Cooper pair. Thus it would seem that the 3-braid system in question automatically produces 1-qubit representation of 3-braid group.

2. The braiding matrices $\Phi(s_1)$ and $\Phi(s_2)$ are different and only $\Phi(s_2)$ mixes qubit values. This can be interpreted as the presence of two inherently different braid operations such that only the second braiding operation can generate entanglement of states serving as building blocks of logical qubits. The description of anyons as 2-dimensional wormholes led to precisely this picture. The braid group reduces to braid group for one half of anyons since anyon and its partner at the end of wormhole are head and feet of single dancer, and the anyon pair (AA) forming bound state can change partner during swap operation with anyon A and this generates quantum entanglement. The swap for anyons inside (AA) can generate only relative phase.

3. The vanishing of the topological charge in a pairwise manner is the symmetry which reduces the dimension of the representation space to 2^{n-1} as already found. For $n = 4$ only single topological qubit results. The conservation and vanishing of the net topological charge inside each batch gives a constraint, which is satisfied by the maximally entangling R-matrix R so that it could take care of braiding between different 4-batches and one would have different braid representation for 4-batches and braids consisting of them. Topological quantization justifies this picture physically. Only phase generating *physical* 1-gates are allowed since Hadamard gate would break the conservation of topological charge whereas for *logical* 1-gates entanglement generating 2-gates can generate mixing without the breaking of the conservation of topological charges.

Summary

It deserves to summarize the key elements of the proposed model for which the localization (in the precise sense defined in [B41]) made possible by topological field quantization and Z_4 valued topological charge are absolutely essential prerequisites.

1. $2n$-anyon system has 2^{n-1}-fold ground state degeneracy, which for $n = 2$ leaves only single logical qubit. In standard physics framework $(AA)-A-A$ is minimal option because the total homology charge of the system must vanish. In TGD $(AA)-A$ system is enough to represent 3-braid system if the braid operation between AA and A can be realized as an exchange of the dancing partner. This option makes sense because the anyons with opposite topological charges at the ends of wormhole threads can be negative energy anyons representing the final state of the braid operation. A pair of magnetic flux tubes is needed to realize single anyon-system containing braid.

2. Maximally entangling R-matrix realizes braid interactions between $(AA)-A$ systems realized as 3-braids inside larger braids and the space of logical qubits is equivalent with the space of realizable qubits. The topological charges are conserved separately for each $(AA)-A$ system. Also the more general realization based on n-braid representations of Temperley-Lieb algebra is formally possible but the different topological realization of braiding operations does not support this possibility.

3. Temperley-Lieb 3-braid representation for $(AA)-A-A$ system allows to realize also 1-gates as braid operations so that topology would allow to avoid the fine-tuning associated with 1-gates. Temperley-Lieb representation for $\phi = exp(i\pi/10)$ satisfies all basic constraints and provides representation of the modular functor expressible using $k = 3$ Witten-Chern-Simons action. Physically 1-gates are realizable using Φ_1 acting as phase gate for anyon pair inside (AA) and $\Phi(s_2)$ entangling (AA) and A by partner exchange. The existence of single qubit braid representations apparently conflicting with the identification of topological entanglement as a correlate of quantum entanglement has an explanation in terms of quantum computation under topological symmetries.

3.5.3 Zero Energy Topological Quantum Computations

As already described, TGD suggests a radical re-interpretation for matter antimatter asymmetry in long length scales. The asymmetry would be due to the fact that ground state for fermion system corresponds to infinite sea of negative energy fermions and positive energy anti-fermions so that fermions would have positive energies and anti-fermions negative energies.

The obvious implication is the possibility to interpret scattering between positive energy states as a creation of a zero energy state with outgoing particles represented as negative energy particles. The fact that the quantum states of 3-dimensional light-like boundaries of 3-surfaces represent evolutions of 2-dimensional quantum systems suggests a realization of topological quantum computations using physical boundary states consisting of positive energy anyons representing the initial state of anyon system and negative energy anyons representing the outcome of the braid operation.

The simplest scenario simply introduces negative energy charge conjugate of the $(AA)-A$ system so that no deviations from the proposed scenario are needed. Both calculation and its conjugate are performed. This picture is the only possible one if one assumes that given space-time sheet contains either positive or negative energy particles but not both and very natural if one assumes ordinary fermionic vacuum. The quantum computing system would could be generated without any energy costs and even intentionally by first generating the p-adic space-time sheets responsible for the magnetic flux tubes and anyons and then transformed to their real counterparts in quantum jump. This double degeneracy is analogous to that associated with DNA double strand and could be used for error correction purposes: if the calculation has been run correctly both anyon Cooper pairs and their charge conjugates should decay with the same probability.

Negative energies could have much deeper role in TQC. This option emerges naturally in the wormhole handle realization of TQC. The TGD realization of 1-gates in 3-braid Temperley-Lieb representation uses anyons of opposite topological charges at the opposite ends of threads

connecting magnetic flux tube boundaries. Single 3-braid unit would correspond to positive energy electronic anyons at the first flux tube boundary and negative energy positronic anyons at the second flux tube boundary. The sequences of 1-gates represented as 3-braid operations would be coded by a sequence of 3-braids representing generators of 3-braid group along a pair of magnetic flux tubes. Of course, also n-braid operations could be coded in the similar manner in series. Hence TQC could be realized using only two magnetic flux tubes with n-braids connecting their boundaries in series.

Condensed matter physicist would probably argue that all this could be achieved by using electrons in strand and holes in the conjugate strand instead of negative energy positrons: this would require only established physics. One can however ask whether negative energy positrons could appear routinely in condensed matter physics. For instance, holes might in some circumstances be generated by a creation of an almost zero energy pair such that positron annihilates with a fermion below the Fermi surface. The signature for this would be a photon pair consisting of ordinary and phase conjugate photons.

The proposed interpretation of the S-matrix in the Universe having vanishing net quantum numbers encourages to think that the S-matrices of 2+1-dimensional field theories based on Witten-Chern-Simons action defined in the space of zero (net) energy states could define physical states for quantum TGD. Thus the 2+1-dimensional S-matrix could define quantum states of 4-dimensional theory having interpretation as states representing "self-reflective" level representing in itself the S-matrix of a lower-dimensional theory. The identification of the quantum state as S-matrix indeed makes sense for light-like surfaces which can be regarded as limiting cases of space-like 3-surfaces defining physical state and time-like surfaces defining a time evolution of the state of 2-dimensional system.

Time evolution would define also an evolution in topological degrees of freedom characterizing ground states. Quantum states associated with light-like (with respect to the induced metric of space-time sheet) 3-dimensional boundaries of say magnetic flux tubes would define quantum computations as modular functors. This conforms with quantum-classical correspondence since braids, the classical states, indeed define quantum computations.

The important implication would be that a configuration which looks static would code for the dynamic braiding. One could understand the quantum computation in this framework as signals propagating through the strands and being affected by the gate. Even at the limit when the signal propagates with light velocity along boundary of braid the situation looks static from outside. Time evolution as a state could be characterized as sequence of many-anyon states such that basic braid operations are realized as zero energy states with initial state realized using positive energy anyons and final state realized using negative energy energy anyons differing by the appropriate gate operation from the positive energy state.

In the case of n-braid system the state representing the S-matrix $S = S^1 S^2 .... S^n$ associated with a concatenation of n elementary braid operations would look like

$$\begin{aligned} |S\rangle &= P_{k_1} S^1_{k_1 k_2} P_{k_2} S^2_{k_2 k_3} P_{k_3} S^3_{k_3 k_4} \cdots \ , \\ P_k &= |k, <\rangle |k, >\rangle \ . \end{aligned} \tag{3.5.4}$$

Here S^k are S-matrices associated with gates representing simple braiding operations s_k for $n+1$ threads connecting the magnetic flux tubes. P_k represents a trivial transition $|k\rangle \to |k \to k\rangle$ as zero energy state $|k, > 0\rangle |k, <\rangle$. The states P_k represent matrix elements of the identification map from positive energy Hilbert space to its negative energy dual.

What would happen can be visualized in two alternative ways.

1. For this option the braid maps occur always from flux tube 1 to flux tube 2. A braiding transition from 1 to 2 is represented by S^{k_1}; a trivial transition from 2 to 1 is represented by P_k; a braiding transition from 1 to 2 is represented by S^{k_2}, etc... In this case flux tube 1 contains positive energy anyons and flux tube 2 the negative energy anyons.

2. An alternative representation is the one in which P_k represents transition along the strand so that S^k *resp.* S^{k+1} corresponds to braiding transition from strand 1 to 2 *resp.* 2 to 1. In this case both flux tubes contain both positive and negative energy anyons.

3.6 Quantum computations without definite causal structure: TGD view

I encountered a link to a interesting popular article *"Causal Witness" Provides First Experimental Evidence Of Indefinite Causal Order* (see `http://tinyurl.com/lwaurk3`). The article tells about an article *Experimental verification of an indefinite causal order* by Rubio *et al* [B26](see `http://tinyurl.com/ltamjbv`). In the following are my first impressions.

In TGD Zero Energy Ontology (ZEO) replaces ordinary ontology and the arrow of time is not fixed, and it is interesting to see whether superposition of different causal orders related by time inversion T for causal diamond (CD) and SWITCH could be realized in ZEO. The twistor lift of TGD leads to the proposal that CD is accompanied by a Minkowskian generalization of self-dual Kähler form $J(CD)$. Although the moduli space of CDs allows to avoid breaking of Poincare invariance, self-duality of $J(CD)$ leads to violation of T implying that different causal orders correspond to disjoint sectors of "world of classical worlds". This makes possible also superposition of different causal orders and SWITCH would map these sectors to each other.

3.6.1 Indefinite causal order

The abstract of the article Rubio *et al* might give some idea about what is involved.

Investigating the role of causal order in quantum mechanics has recently revealed that the causal relations of events may not be a priori well-defined in quantum theory. Although this has triggered a growing interest on the theoretical side, creating processes without a causal order is an experimental task. We report the first decisive demonstration of a process with an indefinite causal order. To do this, we quantify how incompatible our setup is with a definite causal order by measuring a "causal witness". This mathematical object incorporates a series of measurements that are designed to yield a certain outcome only if the process under examination is not consistent with any well-defined causal order. In our experiment, we perform a measurement in a superposition of causal orders—without destroying the coherence—to acquire information both inside and outside of a causally non-ordered process. Using this information, we experimentally determine a causal witness, demonstrating by almost 7 SDs that the experimentally implemented process does not have a definite causal order.

Unfortunately, I do not have prerequisites to say anything interesting about the delicacies of the experiment itself. Since causal order is fixed by that associated with space-time in standard physics, the implications of the experiment could be world view changing. The key quantum information theoretic notions are causal order, causal separability, quantum wittness, quantum process called SWITCH changing causal order, and superposition of causal orders.

1. The notion of causal order is discussed in the article "Quantum correlations with no causal order" by Oreshkov *et al* [B43] (see `http://tinyurl.com/l7wb5zh`). One has two events A and B. If they are causally separable, one can tell which causes which. In Minkowski space causally separable events would connected by a time-like curve. If not, one cannot speak about causal order. One can tell whether A precedes B or vice versa. For light-like distances, the situation is not so clear.

   Relaxing the standard assumption about fixed arrow of time one can at quantum level consider also a situation in which one has quantum superposition of different causal orders. One has causal non-separability.

2. The notion of causal wittness [B20] (see `http://tinyurl.com/jwzo3lq`) provides a method allowing to deduce experimentally whether the process is causally separable or not. The notion is similar to that of entanglement wittness (see `http://tinyurl.com/mwjb7um`) allowing to deduce whether the two systems are entangled. Essentially one has observable whose expectation is negative for states with indefinite causal order and positive for those with definite causal order. Causal wittness is not universal but must be constructed for each causally indefinite state separately. The construction of causal wittness expectation value of operator is far from trivial and requires deeper understanding of operator theory. The abstract definition goes as follows:

Causal wittness represents a set of quantum operations, such as unitaries, channels, state preparations, and measurements, whose expectation value is non-negative as long as all the operations are performed in a definite causal order, i.e., as long as only causally separable resources are used. The observation of a negative expectation value is thus sufficient to conclude that the operations were not performed in a definite order.

Causal witness can be constructed efficiently and the construction is discussed in [B21] (see `http://tinyurl.com/lxer962`).

3. SWITCH is a further basic notion. One has two events A and B, which can be connected by a time-like curve. One can tell whether A precedes B or vice versa. SWITCH is a quantum operation switching the causal order. The obvious manner to do this would permute A and B and would require "time travel" not allowed in standard physics. Obviously, SWITCH cannot be realized as operation respecting fixed causal order.

4. If superpositions of causal orders are possible, one can have a situation in which causal order is indefinite. Also this is something which does not conform the ordinary view about physics in fixed space-time but is allowed by postulates for quantum computation and SWITCH represents an example of quantum computation impossible with a fixed causal order.

Needless to say, the notions of causal order and superposition of causal orders are revolutionary ideas and the article claims that they have been experimentally verified. Standard physics framework does not allow SWITCH. Therefore there are excellent motivations to find whether these notions and the operation of SWITCH could be understood in TGD framework.

In TGD Zero Energy Ontology (ZEO) replaces ordinary ontology and the arrow of time is not fixed, and it is interesting to see whether superposition of different causal orders related by time inversion T for causal diamond (CD) and SWITCH could be realized in ZEO. The twistor lift of TGD leads to the proposal that CD is accompanied by a Minkowskian generalization of self-dual Kähler form $J(CD)$ [K11, L39]. Although the moduli space of CDs allows to avoid breaking of Poincare invariance, self-duality of $J(CD)$ leads to violation of T implying that different causal orders correspond to disjoint sectors of "world of classical worlds". This makes possible also superposition of different causal orders and SWITCH would map these sectors to each other.

3.6.2 ZEO and discrete symmetries for twistor lift of TGD

Some background about TGD is necessary in order to proceed.

1. Zero Energy Ontology (ZEO) is the cornerstone of TGD and TGD inspired theory of consciousness. Zero energy states appear as two variants and correspond to different WCW spinor fields (WCW for "world of classical worlds"). I have proposed that they correspond also to WCW spinor fields localized to different sectors of WCW but this might be unnecessarily strong assumption.

   Zero energy states for given basis have been subject to a state function reduction at either boundary of CD - passive boundary. Neither the passive boundary nor the members of state pairs at it appearing in the superposition of state pairs are affected in repeated state function reductions. One has what I have called generalized Zeno effect identified as conscious entity - self.

   At the opposite boundary the states evolve: every state function reduction at active boundary is preceded by a unitary time evolution ending to a localization of the active boundary of CD, which can be also seen as a state function reduction [L40]. The temporal distance between the tips of CD increases in this process and gives rise to clock time and experienced flow of time.

   Eventually the first reduction to the opposite boundary occurs and the roles of active and passive boundary of CD are changed. One can say that time reversed zero energy state is obtained and begins to evolve. The first reduction to the opposite boundary would mean death of the conscious entity defined by the sequence of state function reductions at the same boundary and generation of time reversed re-incarnation of self.

2. Violation of T - to be discussed below - would also imply asymmetry between selves and their time reversals. For instance, the average duration for the state reduction sequences keeping boundary fixed could be different and second causal order could dominate giving rise to a dominating arrow of time. Since these reduction sequences are identified as correlates for conscious selves, the time reversed re-incarnations would live much shorter time. Biological systems might be an exception: in TGD inspired theory of consciousness sensory perception and motor action are time reversals of each other.

3. Fermionic oscillator operators associated with induced spinor fields allow to represent WCW gamma matrices as their linear combinations: Fermi statistics is geometrized. Fermionic oscillator operators define also quantum Boolean algebra in the sense that fermion numbers 1/0 correspond to the two Boolean values. One could say that quantum logic is square root of WCW Kähler geometry. This allows to interpretation the S-matrix for fermions as quantum Boolean map between quatum Boolean algebras at opposite boundaries. This is obviously important when one talks about quantum computation.

   In the approach to twistor amplitudes [K40, L39] fermions are localized at the boundaries of string world sheets defining light-like curves at the 3-D light-like orbits of partonic 2-surfaces, at which the signature of the induced metric changes from Minkowskian to Euclidian and has a vanishing determinant so that tangent space is effectively 3-D. The interpretation is in terms of strong form of holography (SH) stating that the data determining both space-time surface as preferred extremal and modes of the induced spinor field in the interior of space-time surface. SH predicts that both the bosonic and fermionic 4-D actions reduce to 2-D effective actions for string world sheets.

   The implication is that fermion states at the boundaries of CD are localized at discrete points of partonic 2-surfaces. One has of course amplitude over different locations of fermions at partonic 2-surfaces. The presence of fermionic string world sheets correlates the fermions at different partonic 2-surfaces and serves as correlate for entanglement in fermionic degrees of freedom.

4. The twistor lift of TGD [K40, K11, L39] has led to a rather detailed understanding of discrete symmetries CP, P,T. If M^4 factor of embedding space - or more precisely CD - is endowed with a generalized *self-dual* Kähler form $J(M^4)$ (analogs of magnetic and electric fields of same magnitude and direction), new violations of CP, P and T occurring in long scales and having no counterpart in standard model emerge. The reason is that CP, P and T do not respect the self-duality of M^4 Kähler form. The violations of Poincare invariance are avoided if one assumes moduli space for CDs containing the Lorentz boosts and translations of CD.

   The first guess is that T leaving the center point of CD invariant applied to the CD maps the 3-surfaces at the boundaries of CD to each other. The violation of T however implies that the image of the pair need not allow preferred extremal (space-time surface) connecting its members.

   One can however define the temporal mirror image of pair by mapping only the 3-surface at the passive boundary to the opposite boundary: preferred extremal property would determine the 3-surface at the passive boundary. This could imply that the sub-WCWs formed by pairs and the time reversals are disjoint and form different sectors of WCW as indeed assumed in [L40]. This realization of T allows also the possibility that the dynamics of preferred extremals is not strictly deterministic (true at least for p-adic space-time sheets).

   In absence of T violation T operation would also permute the values fermionic states partonic 2-surfaces at the boundaries of CD but if T is violated, can map only the state at the passive boundary to the opposite boundary and determine the state at original boundary from the hermitian conjugate of S-matrix in opposite time direction. The fermionic state at the opposite boundary would be superposition of states having only same total quantum numbers as the state at the passive boundary. The quantum numbers of individual fermions would not be sharp for non-trivial S-matrix if the zero energy states and their T images correspond to same sector of WCW.

   If T is not violated, zero energy states and their T-images would not correspond to the same sector of WCW. Obviously they would correspond to opposite causal orders, see below) This

would force to give up the assumption that states at passive boundary are state function reduced. If T is violated globally, the zero energy states and their T-reversals would correspond to disjoint sectors of WCW, and the sectors would only correspond to different arrows of time. This option gives hopes about WCW localization the outcome of the measurement of causal order.

The union of sub-WCWs with opposite arrow of time is a space with fixed causal order plus additional binary digit characterizing the causal order. The state function for this binary digit could fix the causal order and quantum computation generating superposition of causal orders should generate entanglement with this bit.

5. What about the situation for a union of CDs? Different CDs should be able to have their own arrow of time. For instance, there are reasons to think that in living matter one can have subsystems with non-standard arrow of time [J30]. Also phase conjugate laser ray could be also example of this. This requires that WCW spinor fields associated with a union of CDs form a tensor product. Causal order need not be same for all CDs but characterizes the sub-WCW associated with CD forming a Cartesian factor of WCW so that WCW spinors for the CDs form tensor product.

3.6.3 Two views about SWITCH and superposition of causal orders

One can imagine two approaches to the identification of SWITCH operation and superposition of causal orders.

Option I: Unitary SWITCH as time reversal

The first option corresponds to corresponds to unitary "time travel" option.

1. As already proposed, SWITCH as a unitary operation could correspond to T. Time reversal operation T applied to the 3-surfaces at the boundaries of CD would naturally change the causal order for the zero energy state. If T is violated the state and its T-image belong to separate sectors of WCW. One could also have a superposition of zero energy states related by T and having different causal orders and localizable to the two sectors of WCW.

2. Is it possible to perform SWITCH as a unitary (as a matter fact, antiunitary) operation? If T maps the disjoint sectors to each other and maps fermionic time evolutions to their time reversals, SWITCH maps the two sectors of WCW to each other.

   Can one realize SWITCH mathematically as a unitary operation between fermionic state spaces. This seems possible: the tensor product of $S \otimes S^\dagger$ on tensor product of fermionic Fock spaces would realize this map. Whether SWITCH can be realized physically is of course another question.

Option II: Non-unitary SWITCH as the first state function reduction to the opposite boundary of CD

Could non-unitary SWITCH be realized as the first state function reduction to the opposite boundary - death of self followed by a re-incarnation as time-reversed self? In this case SWITCH is neither unitary nor deterministic. This SWITCH corresponds to non-unitary "time travel" option in the sense that self identified as passive boundary makes a time travel to the opposite boundary of CD by re-incarnating in non-deterministic manner.

What about the superposition of self and time reversed self as a superposition of causal orders? Schrödinger cat would be more than a catchy metaphor: it would indeed be a superposition of cat and re-incarnated cat! Should one take this seriously?

If the CDs with different arrow of time correspond to different sectors of WCW, different causal orders correspond to states localized in these sectors. A superposition of causal orders would correspond to WCW spinor field having component in both these sectors. If the state function reduction to opposite boundary of CD takes place at the level of entire WCW - or more realistically, for a Cartesian factor of WCW, it must be accompanied by a localization to either sector of WCW in order to avoid paradoxes.

I have already earlier work with TGD inspired ideas related to quantum computation. For more than decade ago I developed rather speculative model topological quantum computation in TGD framework [K3, K106]. One speculation about super-effective quantum computations is inspired by the analogy of selves with quantum computations halting, when the self dies and re-incarnates as time reversed self with clock time running in opposite direction at opposite boundary of CD [K7]. This would mean using the non-unitary SWITCH realized as state function reduction in quantum computation.

This allows to imagine a series of quantum computations at opposite boundaries proceeding as a sequence of re-incarnations so that the size of CD and thus clock time would grow in opposite directions during subsequent incarnations [L30]. Although the re-incarnation as time reversed self could have long life-time, it would not be seen by an observer near the former re-incarnation and the re-re-incarnation would appear at clock-time, which need not be much later than the time of previous death. One could imagine that the time-reversed selves could have very long life-time or that the self could die and re-incarnate very many times without any-one noticing it! The large amount of time spent in time reversed mode could explain the miraculous cognitive feats of mathematicians like Ramajunan and also the magic computational abilities of idiot savants able to factorize large integers without any idea about the notion of prime.

3.6.4 Higher level quantum computations and ZEO

From the article of Rubio *et al* one ends up to an article *Quantum computations without definite causal structure* by Chiribella *et al* (see `http://tinyurl.com/lgjkzhx`). The article considers a rather far reaching generalization of quantum computation. Ordinary quantum computation is a time evolution of quantum states followed by a state function reduction. Since the outcome of state function reduction halting the quantum computer program is non-deterministic, the extraction of the result involves statistical averaging over a large enough number of quantum computations to get the outcome, say prime factorization or a period of periodic function.

The notion of classical computation is generalized by Church. The computation need not be a function but can assign function to a function. One can continue this abstraction hierarchy indefinitely and it is realized formally in terms of so called Λ calculus (see `http://tinyurl.com/829fea8`). Could this hierarchy be extended to quantum computations? The quantum computation in question would be kind of super-computation assigning to quantum computation a quantum computation and entire hierarchy of quantum computations.

In TGD this kind of hierarchies emerge naturally. At space-time level there is hierarchy of space-time sheets: space-time sheet is (topologically) condensed to a larger space-time sheet and contains smaller space-time sheets condensed at it. The hierarchy of infinite primes corresponds to an infinite hierarchy of second quantizations and could relate to this hierarchy [K94] (see `http://tinyurl.com/m3tuo9q`. In each scale space-time sheets would be particles consisting of smaller particles consisting of ... Even galaxy could be seen as elementary particle in some scale characterizing the galactic space-time sheet.

The analog of quantum computational hierarchy emerges quite concretely in ZEO. The simplest zero energy states have positive and negative energy states with opposite total quantum numbers at the opposite boundaries of CD (intersection of future and past directed light-cones). One can have CDs within CDs. Furthermore, the positive/negative energy states assignable to the boundaries of CD could be also zero energy states associated with smaller CDs near the boundaries of CD. The simplest zero energy states correspond to quantum evolution representing ordinary quantum computation. Higher level zero energy stats would represent time evolution assigning to a quantum computation represented as zero energy state at the boundary of CD a second quantum computation at opposite boundary of CD.

The fermionic representation of quantum Boolean algebra makes this hierarchy quite concrete. At lowest level unitary evolution connects positive and negative energy fermionic states at opposite boundaries of CD and unitary S-matrix characterizes the computation. Higher level computations connect zero energy states assignable to sub-CDs near the boundaries of CD.

3.6.5 Is conscious experience without definite causal order possible?

The exciting question is what the superposition of causal orders could mean from the point of view of conscious experience. What seems obvious is that in the superposition of selves with opposite arrows of clock-time there should be no experience about the flow of time in definite direction. Dissipation is associated with the thermodynamical arrow of time. Therefore also the sensory experience about dissipation expected to have unpleasant emotional color should be absent. This brings in mind the reports of meditators about experiences of timelessness. These states are also characterized by words like "bliss" and "enlightenment".

Why I find this aspects so interesting is due to my personal experience for about 32 years ago. I of course know that this kind of personal reminiscences in an article intended to be scientific, is like writing one's own academic death sentence. But I also know I long ago done this so that I have nothing to lose! The priests of the materialistic church will never bother to take seriously anything that I have written so that it does not really matter! This experience - I dared to talk about enlightenment experience - changed my personal life profoundly, and led to the decision to continue work with TGD instead of doing full-day job to make money and keeping TGD as a kind of hobby. The experience also forced to realize that our normal conscious experience is only a dim shadow of what it can be and stimulated the passion to understand consciousness.

In this experience my body went to a kind of light flowing state: liquid is what comes in mind. All unpleasant sensations in body characterizing the everyday life (at least mine!) suddenly disappeared as this phase transition propagated through my body. As a physicist I characterized this as absence of dissipation, and I talked to myself about a state of whole-body consciousness.

There was also the experience about moving in space in cosmic scales and the experience about the presence of realities very different the familiar one. Somehow I saw these different worlds from above, in bird's eye of view. I also experienced what I would call time travel and re-incarnation in some other world.

Decades later I would ask whether my sensory consciousness could have been replaced with that only about my magnetic body only. In the beginning of the experience there was indeed a concrete feeling that my body size had increased with some factor. I even had the feeling the factor was about 137 (inverse of the fine structure constant) but this interpretation was probably forced by my attempt to associate the experience with something familiar to physicist! Although I did all the time my best to understand what I was experiencing, I did not direct my attention to my time experience, and cannot say whether I experienced the presence or absence of time or time flow.

Towards the end of the experience I was clinically unconscious for about day or so. I was however conscious. For instance, I experienced quite concretely how the arrow of time flow started to fluctuate forth and back. I somehow knew that permanent change would mean death and I was fighting to preserve the usual arrow of time. My childhood friend, who certainly did not know much about physics, told about about alternation of the arrow of time during a state that was classified by psychiatrists as an acute psychosis.

3.7 Retrocausality and TGD

The comments below were inspired by a popular article "Physicists provide support for retrocausal quantum theory, in which the future influences the past" in Phys.org (see `http://tinyurl.com/yd4rwsg7`) telling about the preprint "Is a time symmetric interpretation of quantum theory possible without retrocausality?" of Leifer and Pusey related to the notion of retrocausality [B42] (see `http://tinyurl.com/yd59jvd5`). Retrocausality means the possibility of causal influences propagating in non-standard time direction. Retrocausality has been also proposed by Cramer as a possible manner to obtain deterministic quantum mechanics and allowing to interpret wave functions as real objects. Bell theorem and Kochen-Specker theorem however pose difficult challenges for this program and the condition that the theory is classical in strong sense (all observables have well-defined values) seems impossible.

The work is interesting from TGD view point for several reasons.

1. TGD leads to a new view about reality solving the basic problem of quantum measurement theory. In ZEO quantum states are replaced by zero energy states which are analogous to pairs of initial and final states in ordinary ontology and can be regarded as superpositions

of classical deterministic time evolutions. The sequence of state function reductions means sequence of re-creations of the superpositions of classical realities. The TGD based view about scattering amplitudes has a rather concrete connection with the view of Cramer as I interpret it. There is however no attempt to reduce quantum theory to a purely classical theory. The notion of "world of classical worlds" consisting of classical realities identified as space-time surfaces replaces space-time as a fixed observer independent reality in TGD.

2. Retrocausality is basic aspect of TGD. Zero Energy Ontology (ZEO) predicts that both arrows of time are possible. In this sense TGD is time symmetric. On the other hand, the twistor lift of TGD predicts a violation of time reflection T and this might imply that second arrow of causality dominates in some sense. The ZEO based view about state function reduction essential for TGD inspired theory of consciousness and implying generalized Zeno effect giving rise to conscious entities -"selves" - is also essential. One might say that when conscious entity dies it re-incarnates as time-reversed self.

3. The possibility of superposing states with opposite causal arrows [B26] (see `http://tinyurl.com/ltamjbv`) is a fascinating idea and its plausibility is discussed already earlier in TGD framework [L38] (see `http://tinyurl.com/y9tgfxbf`).

In the sequel I will discuss the articles from TGD point of view criticizing the hidden assumptions about the nature of time leading to the well-known problems of quantum measurement theory and consider also the concrete implications for theories of consciousness. Also the empirical evidence for retrocausality is discussed briefly. Contrary to the article the discussion is non-technical: I do not believe that the introduction of technicalities helps to understand the deep conceptual problems involved and possible solutions to them.

3.7.1 Retrocausality

In this section I will explain my own view about retrocausality but will not introduce the TGD view yet.

Retrocausality: with or without real quantum states

Leifer and Pusey use as a starting point the work of Hue Price [B34] (see `http://tinyurl.com/yaa8wogr`), which claims that if quantum states are real and quantum world is time-symmetric then theory must allow retrocausal influences.

What does one mean when one says that quantum states are real? In standard ontology (PEO) this is usually taken to mean that physics is deterministic and universe corresponds to single solution of field equations. This leads of course to conflict with the facts behind quantum measurement theory. State function reductions are not deterministic. This has led to various interpretations such as Copenhagen interpretation giving up ontology altogether and assuming only epistemology: wave function describes only our knowledge about something, which does not exist. One has paradox.

Retrocausality has been proposed to save the notion of reality as something unique and deterministic. A stronger condition is that all observables have sharp values as in classical mechanics. For Schrödinger amplitudes - which can be seen also as purely classical objects - the observables are defined by expectation values of operators and simultaneous eigenstates of non-commuting observables are not possible and classicality in strong sense fails.

Cramer's transcactional interpretation of quantum theory (see `http://tinyurl.com/zpupb8g`) indeed assumes that both causal arrows are possible.

1. To my best understanding this would mean that there are two time evolutions: the usual one from past to future and the retrocausal one from future to past. At some 3-dimensional hyper-surface of space-time these time evolutions would meet each other and be glued together. At this hyper-surface there would be discontinuities. This picture might lead to the standard statistical predictions of quantum measurement theory such as reduction probabilities if the two states would correspond to eigenstates of corresponding measured observables and transition amplitudes are given by Born rule. Note that Cramer's theory is completely deterministic and there is no room for free will.

2. Realism should be consistent with the experimentally verified Bell theorem supporting non-locality of quantum theory made possible by quantum entanglement. The hope is that retrocausality is consistent with Bell theorem predicting correlations between distant measurements not possible to understand in terms of classical probabilities. The key point is the interference of amplitudes which in quantum theory replaces summation of probabilities.

3. There is also Kochen-Specker theorem (see `http://tinyurl.com/q4vb9j5`) stating that it is not possible to have classical description of all quantum observables when their algebra is non-commutative. If realism is taken to mean that all observables have well-defined values then there is no hidden variable theory allowing realism. Even retrocausality can help only if realism is formulated in less demanding manner.

Leifer and Pusey give up the debatable assumption about reality of quantum states and claim of having proved the same result. The article is rather technical and I have not checked the details. Intuitively the result of course looks rather obvious. Of course, it is possible that theory is not fully time-symmetric and there are still retrocausal influences. For instance, the violation of time reflection symmetry and this could make the ordinary causal influences longer lasting than the retrocausal ones.

Cannot have both time symmetry and no-retrocausality

Leifer and Pusey show that time symmetry and non-allowance of retrocausality leads to a contradiction but they do not assume the reality of quantum states in the sense of PEO. Time symmetry implies that forward and backward processes have same probabilities. Impossibility of retrocausality obviously requires that the probabilities for retrocausal processes vanish.

Intuitively it is clear that time symmetry is more or less equivalent with the possibility of retrocausality meaning possibility of signals propagating in non-standard time direction. There are however many poorly understood issues.

1. What does one mean with signal? How can one conclude that the time evolution of say electromagnetic field corresponds to signal (or influence) in a given time direction? One possibility is that positive frequency photons correspond to signals to future. In quantum field theories (QFTs) positive energy photons correspond to creation operators and negative energy photons to annihilation operators. By $E = hf$ and its generalization positive frequencies correspond to positive energies. This would code for the selection of arrow of time and causality. This selection has nothing to do with thermodynamics and second law. One could call this ontology positive energy ontology (PEO).

2. It is far from obvious whether the time of physicist geometrized by Einstein can be identified with the experienced time is correct. This identification is done also in the work of Leifer and Pusey. The arrow of time is naturally assignable to subjective time but not to geometric time. Certainly these two times correlate strongly. We can experience subjective time directly but also use physical processes such as oscillators serving as clocks measuring geometric time, and this gives correspondence between the sequence of mental images and the position of the pointer of the clock.

   This strong correlation does not justify the identification of the two times. For instance, subjective time seems to have no future, only the moment "Now" is experienced directly, and there are only memories (even sensory ones) about the past. Geometric time has no preferred value and seems to correspond to eternity. There are therefore dramatic differences between the two times but for some reason they are usually identified.

3. Thermodynamics and second law are certainly closely related to subjective time. Thermodynamical predictions in turn rely kinetic theory with various reaction rates deduced from quantum theory. Non-determinism of state function reduction is what gives to the second law basically. Entropy increases due to state function reduction in the direction of time, which corresponds to a direction in which energies (frequencies for photons) are positive. If subjective time and geometric time are not identified this assumption becomes questionable and one can wonder whether the causal arrow is property of Universe or of quantum state only.

For instance, could thermodynamical arrow correspond to non-standard arrow of geometric time?

What time symmetry would mean if one does not identify subjective and geometric time? Is there symmetry with respect to subjective or geometric time or both? Could the causal arrow be a property of quantum state? Is it possible to have both causal arrows without conflict with second law or should one generalize second law so that it applies in reverse direction of geometric time for systems allowing retrocausality?

3.7.2 The notions of reality and retrocausality in TGD context

Consider next what one can say about the notion reality and retrocausality in TGD framework.

About the notion of reality in TGD framework

In TGD framework the question about the relationship between geometric and experienced time leads to a new view about state function reduction solving the basic paradox of standard quantum measurement theory and forces to replace the notion of classical reality with quantum superposition of realities. The new notions are "world of classical worlds" (WCW) and zero energy ontology (ZEO).

1. The key question is whether subjective and geometric time are identical. Could it be that these times are not same? If so, one would have two causalities: causality of state function reductions and causality of field equations. Could state function reductions occur between entire deterministic time evolutions rather than tinkering with single time evolution making it non-deterministic?

   This would force to give up the idea about single 4-D reality and replace it with a space of realities. In quantum theory one would be forced to speak of quantum superposition of these classical realities. Each state function reduction would re-create the superposition of 4-D classical realities identified as deterministic time evolutions. One would have realism in more general sense: quantum states would be quantum superpositions of classical realities giving rise to the "world of classical worlds" (WCW). Quantum jumps would allow continual re-creation of classical realities making possible evolution.

2. What does one mean with WCW? The notion of WCW from the view about TGD as a generalization of quantum field theory and string models. One replaces point-like particles with 3-D surfaces, whose 4-D orbits have interpretation as space-time surfaces. This of course means a considerable generalization of the notion of space-time. Particles can be seen as smaller space-times glued to larger space-times looking like particles in a rougher resolution.

   Given sector of WCW correspond to the space of space-time surfaces (generalizing particle world lines) inside 8-D causal diamond (CD), which is diamond like intersection of future and past directed light-cones with points replaced with CP_2. By holography these space-time surfaces are determined by 3-D surfaces at opposite boundaries of CD. To be precise, instead of ordinary holography one has strong form of holography (SH) meaning that 2-D data determine the classical dynamics and also quantum dynamics to high extent.

   This view is obviously something new. Classically physical states are not characterized by the initial values - of say coordinates and velocities at *time=constant* snapshot - but by their boundary values at the future and past boundaries of CD. Initial value problem has changed to boundary value problem. One gives initial and final values but only for coordinates, one might say. One has ZEO rather than PEO. This is essential from the point of view of retrocausality.

3. By its infinite-dimensionality WCW Kähler geometry is essentially unique and even the choice of the embedding space as $H = M^4 \times CP_2$ is unique by twistorial considerations [L39]. One might say WCW as the space of classical realities is the unique reality, maybe one should call it **THE REALITY**.

4. The wave functions in WCW correspond to WCW spinor fields. WCW spinors correspond to many-fermion states at given space-time surface and spinor fields are these spinors extended to spinor fields in WCW. All fundamental particles reduce to many-fermion states. This picture is a completely straightforward generalization of the notion of wave function in Minkowski space obtained by replacing point like particles with 3-surfaces. "Center of mass" degrees of freedom for 3-surfaces indeed are indeed characterized by $M^4 \times CP_2$-coordinates.

   These WCW spinor fields can be said to be purely classical spinor fields. There is no second quantization at WCW level. Therefore the only genuinely quantal aspect of quantum TGD would be state function reduction, which makes possible conscious entities with free will and leads to the notion of subjective time besides geometric time.

5. Quantum classical correspondence (QCC) is one of the basic principles of TGD and says that classical physics is exact part of quantum physics. The space-time surfaces in the quantum superposition are preferred extremals of certain action principle. "Preferred" means that SH holds true. In standard path integral approach one would have path integral over all possible space-time surfaces, now only over the preferred extremals. For integrable theories about which TGD seems to be an example, these two views are more or less equivalent. QCC states that the classical Cartan algebra Noether charges for preferred extremals in superposition are identical with eigenvalues of corresponding quantal charges. One could consider even the possibility that all classical Noether charges for the preferred extremals in the superposition are same as the expectation values of their quantum counterparts.

6. Cramer's view about state function reduction as gluing together of causal and retrocausal solutions of field equations together at 3-D surface has a highly interesting analogy in TGD. Elementary particle vertices correspond to this kind of gluing of corresponding space-time surfaces together along their ends [K40, L39]. At partonic level one has analogy of three-particle Feynman vertex. The three external lines of vertex correspond to three 3-D lightlike orbits of partonic 2-surfaces defining boundaries between space-time regions with Minkowskian and Euclidian signature of the induced metric. The vertex corresponds to partonic 2-surface at which these orbits are glued together along their ends. There is also gluing of space-time surfaces along their 3-D ends which could be located to boundaries of a sub-CD within larger CD containing initial and final states of particle reaction at its boundaries. The amplitudes at vertices are obtained using the QFT analog of Born rule.

   QCC would require that each space-time surface in the superposition of space-time surfaces in CD satisfies the Cramer type rules for each vertex involving sub-CD. The superposition of space-time surfaces would be superposition of potential state function reductions! The real state function reduction would pick up of them!

To sum up, in TGD there is no attempt to get rid of the non-determinism of state function reduction or force the reality to be classical in the sense of classical mechanics (local realism with well-defined values for all observables). Classical Noether charges are well-defined for all space-time surfaces but it is impossible to localize WCW spinor field to single space-time surface. This is already impossible by the fact that there is always finite measurement resolution: this notion indeed plays key role in TGD framework and involves p-adic length scale hierarchies and hierarchy of Planck constants labelling dark matter as phases of ordinary matter. Cramer's rule however resembles very strongly the TGD view about classical space-time correlates of particle reactions.

To my view the most precious gift of quantum theory based on ZEO is the possibility to understand free will without conflict with the determinism of basic field equations and various various trying to force old-fashioned reality give up this gift.

ZEO based view about time, state function reduction, and consciousness

In ZEO quantum measurement theory extends to a theory of consciousness: observer ceases to be an outsider and becomes part of the physical world also mathematically. The detailed discussion of various issues and of recent situation of TGD inspired theory of consciousness can be found in [L40].

The basic idea is that consciousness (actually not a property of anything) is in the state function reduction, between the two quantum realities rather than being a property of quantum

reality. This resolves various problems of monistic and dualistic approaches, and one could say that TGD ontology is tri-partistic: classical existence at the space-time level (space-time surfaces), existence at quantum level (zero energy states), and conscious existence at the level of state function reductions. Adelic physics implies further division of realities to "real" and p-adic sectors serving as correlates for sensory and cognitive aspects of conscious experience.

The theory has developed slowly. ZEO meant breakthrough and led gradually through twists and turns to a notion of self surprisingly similar to the original idea. Negentropy maximization principle (NMP) was for a long time regarded as a separate principle but its statistical form follows automatically from adelic physics [L35, L37]. The understanding of the notion of time has been the main challenge.

The basic notion is that of self.

1. Self corresponds to a sequence of quantum jumps integrating to single unit as in the original proposal, but these quantum jumps correspond to repeated state function reductions leaving both the passive boundary of CD and the corresponding parts of zero energy states (state pairs) invariant. The parts of zero energy states at the active boundary of CD change and even the position of the tip of the opposite boundary changes: one actually has wave function over positions of second boundary (CD sizes roughly) and this wave function changes. In positive energy ontology these repeated state function reductions would have no effect on the state (Zeno effect) but in TGD framework there occurs a change for the second boundary and gives rise to the experienced flow of time and its arrow and self: self is generalized Zeno effect.

2. The first quantum jump to the opposite boundary corresponds to the act of "free will" or birth of re-incarnated self. Hence the act of "free will" changes the arrow of psychological time at some level of hierarchy of CDs. The first reduction to the opposite boundary of CD means "death" of self and "re-incarnation" of time-reversed self at opposite boundary at which the the temporal distance between the tips of CD increases in opposite direction. The sequence of selves and time reversed selves is analogous to a cosmic expansion for CD. The repeated birth and death of mental images could correspond to this sequence at the level of sub-selves.

3. This allows to understand the relationship between subjective and geometric time and how the arrow of and flow of clock time (psychological time) emerge. The average distance between the tips of CD increases on the average as along as state function functions occur repeatedly at the fixed boundary: situation is analogous to that in diffusion. The localization of contents of conscious experience to boundary of CD gives rise to the illusion that universe is 3-dimensional. The possibility of memories made possible by hierarchy of CDs demonstrates that this is not the case. Self is simply the sequence of state function reductions at the same boundary of CD remaining fixed and the lifetime of self is the total growth of the average temporal distance between the tips of CD.

4. It is important to notice that one has actually self hierarchy as a counterpart for the existence of hierarchy of systems. Sub-selves correspond to mental images of self, which in turn defines mental image of a higher level self. The proposal is that sub-selves of sub-self are experienced as averages. One might say that TGD predicts pan-psychism in well-defined sense.

   The new view about subsystem makes possible sharing of mental images by entanglement although selves are un-entangled at their own level and thus define separate conscious entities. The new view about subsystem follows naturally from the notion of many-sheeted space-time: space-time sheets can be disjoint although smaller space-time sheets glued to them by wormhole contacts with Euclidian signature of induced metric can have magnetic flux tube connections serving as correlates of attention.

It is clear that selves and their time reversals correspond to causality and retrocausality. Self experiences that signals arrive from geometric past always: the roles of past and future are however changed in the re-incarnation of self.

ZEO can be said to be time symmetric. There is however a breaking of time symmetry in the sense that the twistor lift TGD violates T (and also of CP and P) realized as a time reflection

with respect to the center of CD [L31, L33]. An interesting question is whether this asymmetry could favor the second causal arrow in some sense. For instance, could the life cycles of self with standard arrow of time be considerably longer than those for time reversed selves? This would be due to T-non-invariance of the probabilities for the first reduction to the opposite boundary of CD. Could the longevity in standard time direction emerge in long length scales? For elementary particles the durations of selves are expected to be short since the usual rules for state function reduction apply to the reductions meaning death of self.

There are processes in which the arrow of time seems to be non-standard and a fascinating question is whether these ghostly time reversed selves could be observed, and whether even communications with them could be possible! Some people believe in communications between deceased and alive and study of the communications with deceased is part of parapsychology: could there be some seed of truth in these beliefs?

Possible implications and experimental support for retrocausality

Retrocausality implies that signals can propagate in both directions of time. The signals could even be time reflected at the boundary of CD, which would mean state function reduction changing the arrow of time in the case of signal (note that there is hierarchy of CDs and selves). These reflections could make possible apparently superluminal communications and communication with future and past.

1. The TGD based model for long term memories and precognition relies on the idea that memories involve time reflection from either boundary of CD [K83, **?**, K107, K7].

   The model for motor actions as induced by signals sent to the brain of the geometric past relies on the same idea and explains Libet's strange finding that conscious action is preceded by neuronal activity [J7] used usually to argue that free will is illusion.

   Since the signals propagating to non-standard direction of time has negative energy, one can consider also a model of remote metabolism in which the system needing metabolic energy sends negative energy signal to a system able to provide it, say population reverted laser. This quantum credit card mechanism making possible instantaneous reactions would have obvious evolutionary value and would also favor co-operation.

2. Fantappie [J30] was probably the first theoretical physicist to propose that causal arrow might vary in in living matter and introduced the notion of syntropy, which would correspond entropy growing in nonstandard direction of time. There is quite a number of bio-systems which might be retrocausal at some level. One example is the self-assembly of bio-macromolecules (say tobacco mosaic virus): retrocausally a decay would be in question. Also phase conjugate laser beams [D4, D6] and phase conjugate sound waves are known to obey second law in wrong time direction. For some reason these empirical facts have not captured the attention of theoreticians. In ZEO these findings find a natural explanation.

3. The possibility of time reflection implies that light velocity ceases to be a barrier for communications. One can even speculate with the possibility that conscious entities in distant galaxies could communicate using this mechanism. The altered states of consciousness caused by various psychedelics involve often the experiences about encountering representatives of other civilizations and one can ask whether these encounters are due to remote sensory experiences based on the above mechanism involving both classical and quantum communication (entanglement) [L23] [K100, K97]. Could it be that some sensory receptors (perhaps all) are connections to magnetic flux tubes which can connect the brain to even remote galaxies? If this were the case, one must ask whether our ideas really originate in our brains.

4. One can even imagine that causal arrow is not definite in the sense that one can have quantum states, which are superpositions of states with opposite causal arrows, and there is even a claim that the existence of these states have been verified experimentally by quantum measuring the arrow of causality - causal witness is the name for this observable: see the article *Experimental verification of an indefinite causal order* by Rubio *et al* [B26](see `http://tinyurl.com/ltamjbv`). The popular article *"Causal Witness" Provides First Experimental*

Evidence Of Indefinite Causal Order (see `http://tinyurl.com/lwaurk3`) summarizes the work of Rubio *et al.*

If the finding is real it is revolutionary: in the standard physics framework it is very difficult to imagine how a superposition of different causal arrows could be possible. In the case of superposition of two causal orders the measurement of causal witness has two outcomes and both are claimed to be possible with certain probabilities.

Does TGD allow the superposition of causal arrows? One can obviously decompose the sub-WCW associated with given CD to sectors with well-defined causal arrow: they are related by time reflection T and are indeed different by T violation for classical dynamics. The roles of passive and active boundaries would be changed for the T-related sectors [L38] (see `http://tinyurl.com/y9tgfxbf`). Superposition of causal arrows would mean a state having component in both sectors. This makes sense if state function reduction to the opposite boundary is preceded by the measurement of the causal witness. Therefore the formation of this superposition and refusal to measure causal witness would be a recipe for immortality!

The localizations in the sequence of reductions to the active boundary must occur in complete synchrony for the components in the superposition if they occur at all. A stronger condition is that the two reduction sequences cease so that the time flows stop in both directions: there would be no observables commuting with the observables diagonalized at the passive boundary to be measured anymore [L40]. Does the absence of a well-defined causal arrow alone imply an experience of timelessness or must also the time flow stop? Could the enlightened states reported by meditators and involving experience of timelessness have something in common with this kind of states?

3.8 Still about the notion of causal indefiniteness in TGD framework

The motivation for this comment came from a popular article "*Quantum mischief rewrites the laws of cause and effect*" (`https://cutt.ly/2xEP5Vd`), which tells both about the theoretical work of Lucien Hardy [B38](`https://arxiv.org/pdf/gr-qc/0509120.pdf`) and related experimental work, in particular about the following experimental finding [**?**] (`https://advances.sciencemag.org/content/3/3/e1602589.short`.

Photon beam goes through a spin splitter to form a superposition of photons going along two paths. At the first path they go through A and then through B having some effect on the photons. At second splitter the order of A and B is changed. After that the beams are superposed and it is found that the photons in a causally indefinite state in the sense that the effects of both AB and BA are superposed. In classical physics this is impossible.

The finding is claimed to demonstrate causal indefiniteness: one does not know whether A causes B or B causes A. Classically - that is in the framework provided by fixed causal order dictated by Minkowski space - this seems to be the case.

Is this interpretation correct? Is one really forced to give up causality in the standard form? The rules of standard quantum theory are consistent with the finding but should one change the views about the notion of space-time?

3.8.1 Background

What happens to causality in quantum gravity?

Lightcone of M^4 characterizes the causal structure of Minkowski space in special relativity and is the basic notion of QFTs. In curved space-time of GRT, the light-cone however depends on the metric of space-time. Causal structure is dynamical. The intuitive view is that in quantum gravity causality becomes somehow fuzzy since there is no unique space-time anymore. What this non-uniqueness means is not clear. For instance, could it correspond to what happens in the path integral over space-times?

The problem is that one cannot compare the causal structure for different space-times because the light-cones characterizing them are in different space-times. If the space-times had

common coordinates, the comparison would become possible but one cannot assume this.

Lucien Hardy wanted to understand what happens for causality in quantum gravity [B38]. Hardy proposed a method to test whether events in separate space-time regions are causally related.

1. The method allows to formulate dynamical causality operationally in terms of correlations for measurements performed for regions of space-time. He also introduces the notion of an elementary region from which more complex regions giving rise to causaloids are built. Elementary region corresponds to a space-time region in which some measurement giving a definite result is performed.

   One is interested in the correlations between measurement results associated with disjoint elementary regions and in principle all measurements should reduce to a deduction of such correlations. If two disjoint regions of this kind are causally correlated, the measurement outcomes are correlated. The basic interest is in the conditional probabilities for various outcomes from the measurement of observable F_2 in region R_2 given that the measurement outcome for F_1 in R_1 is known.

   Hardy calls these structures causaloids and proposes that causaloids can be composed to form larger causaloids. No fixed causal structure is assumed and even the notion of time is in principle un-necessary in this formulation for experimental deduction of causal structure. Hardy suggests that the quantization of gravity could be performed using the notion of causaloid.

Quantum switch

Second input comes from quantum computation. Giulio Chiribella and colleagues were interested on what kind of computations are possible [B23] (`https://cutt.ly/wxEJtDF`). Classical computation can be characterized as a recursive function mapping natural numbers to natural numbers. One can build more complex functions from given functions by composition of functions. In classical computation the functions are represented as networks of Boolean gates. In quantum computation the quantum gates are used. Now the situation is more complex, since the outcome of the computation is deduced from the probabilities for various outcomes emerging as the quantum computation halts.

Chiribella and colleagues asked what kind of functions are possible. They ended up with the notion of quantum switch. Beam splitter divides the incoming photon beam to two branches. For the first branch function BA is realizes and for the second branch function AB so that one can speak of two different causal orders. After this the beams superpose. If AB and BA can be realized as causal orders, one could say that the resulting state is causally indefinite. If AB and BA are interpreted as quantum computations wihtout halting one can say that quantum switch realizes a superposition of two computations.

The quantum switch can be realized in the laboratory for the first time by Giulia Rubino *et al* [B27](`https://cutt.ly/pxEH5wQ`. One can measure the polarization of the outgoing photons from the quantum switch to see whether the photons carry information about both AB and BA. This was found to be the case and the findings have been interpreted by saying that that photon experiences causal indefiniteness.

Several technological applications such as communication over noisy channels (`https://cutt.ly/2xEJfVB`) and quantum refrigerator based on indefinite causal order (ICO) (`https://cutt.ly/cxEJcj9`) have been proposed.

Hardy also proposes a Quantum Equivalence Principle [B39] stating that one can find a common reference frame for various deformations of a given space-time metric such that the light-cones of various space-time metrics co-incide in these coordinates at least locally.

3.8.2 TGD view about indefiniteness

In the TGD framework [L61] the basic problem of quantum gravity due to the dynamical nature of causality disappears since the embedding space defines the pre-existing causal structure inducing the causal structure at space-time surfaces.

1. In the TGD framework the space-time of GRT is replaced with a 4-surface in $H = M^4 \times CP_2$. The topology of the space-time surface is non-trivial in all scales which leads to the notion of many-sheeted space-time allowing to reduce matter as shape to the space-time topology. Matter is not something in space-time but topological inhomogenities of space-time surface with size and shape - space-time sheets.

2. The basic conceptual problem in the quantization GRT is due to inability to compare different space-times, in particular their causal structures. This problem disappears in TGD.

   The fixed causal structure of Minkowski space M^4 defines the causal structure with induces causal structures of space-time surfaces in terms of induced metric. One can also quite concretely compare the light-cones of different space-time surfaces determined by the induced metric.

   One can also use M^4 linear coordinates as common coordinates for all space-time surfaces. If the space-time surface does not have 4-D M^4 projection, one can choose a subset of H-coordinates as space-time coordinates. By its maximal symmetries H allows very limited set of preferred coordinates sothat the problems produced by general coordinate invariance are circumvented.

   In TGD framework the surface property of space-time realizes the Quantum Equivalence Principle a at the level of embedding space in the same way as isometries of the space-time as source of conservation laws are lifted to the level of the embedding space.

3. In quantum TGD, also zero energy ontology (ZEO) and causal diamond (CD) are basic notions. CD represents the perceptive field of a conscious entity. The notion of CD resembles the notion of causaloid. One can assign a CD to any quantum system, even elementary particle. CDs form an analog of an atlas consisting of charts and there is a fractal hierarchy with CDs inside CDs, and also overlapping CDs.

4. Zero energy states inside CDs represent particle states as extended objects rather than points. Zero energy states associated with CD correspond to superpositions of space-time surfaces identifiable as preferred extremals of an action principle deriving from the twistor lift of TGD. Minimal surfaces, which are also extermals of so called Kähler action, are in question - minimal surface property geometrizes the notion of massless field and extrelality also for Kähler poses extremely powerful additional conditions guaranteeing Bohr orbit like character of the space-time surface needed to realize general coordinate invariance.

   The important point is that the configurations AB and BA appearing in quantum switch corresponds to a space-time surface represents a branching of 3-surfaces representing photon propagation to two pieces at beam splitter and recombination back to single 3-surface making it possible for the photon wave functions interfere. Causal indefiniteness in the proposed sense does *not* mean that the direction of the causal arrow as an arrow of time is changed and in TGD framework it is not natural to speak about causal indefiniteness.

5. Concerning the understanding of the causality at quantum level in TGD Universe, induction is the key notion. All geometric structures are induced from those of H. This applies to metric, spinor connection, spinor structure, and twistor structure.

   In particular, second quantized spinor field of H is a superposition of modes of the massless Dirac operator of H, which can be solved explicitly and one can calculate Dirac propagator [L63]. The induction of the second quantized spinor field means a restriction to space-time surface and propagators at space-time surface are simply propagators in H. There are no problems with causality since it is induced from H to space-time surfaces.

3.8.3 Also a genuine change of the arrow of time is possible in ZEO

TGD however predicts a different kind of causal anomaly: the arrow of time can change and induce the change of the thermo-dynamical arrow of time [L56].

1. TGD predicts that two kinds of fermionic vacua corresponding intuitively to Dirac seas for which either all negative energy states or positive energy states are filled. They are present also in QFTs but one selects only the second one.

The fermionic creation/annuhilation operators for the first vacuum act like annihilation/creation operators for the second vacuum. In ZEO these two fermionic vacua are associated with the opposite boundaries of CD.

2. Zero energy states as pairs of states assignable to the boundaries of CD. By conservation laws one can say that the total quantum numbers of CD vanish so that the total quantum numbers for the boundaries of CD are opposite.

3. In ZEO [L56, L69] there are two kinds of state function reductions (SFRs): "big" SFRs (BSFRs) as counterparts of ordinary SFRs and "small" SFRs (SSFRs) as counterparts of "weak" measurements as quantum analogs of classical measurements. In BSFRs the arrow of time changes and therefore cause and effect change their roles.

4. Either boundary of the CD is the passive boundary. Neither the passive boundary nor states at it change during the sequences of SSFRs. One can say that the Zeno effect is realized at the passive boundary.Active boundary recedes from the passive boundary in a sequence of scalings of CD followed by SSFRs preceded by unitary time evolutions. Therefore also the states at the active boundary change.

5. In BSFR the active boundary becomes passive and vice versa. The time reversal occurs for dark matter with $h_{eff} = nh_0$ residing at magnetic bodies, and since MB controls the dynamics of ordinary matter, BSFRs for MB induce effective change of the arrow of time for the ordinary matter in scales much longer than it would occur normally in BSFRs in the scale of microcosmos.

6. The change of the thermo-dynamical arrow of time changes in BSFR implies thermo-dynamical anomalies such as generation of gradients observed in systems with a reversed arrow of time [L55]. For instance, the time reversed system can effectively extract thermal energy from the environment. Actually this would be dissipation with a reversed arrow of time. Time reversal also makes self-organized quantum criticality (QSOC) possible [L100], and homeostasis could be seen as the biological manifestation of QSOC.

3.9 Appendix: A 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 described. This view has developed much before the original version of this chapter was written.

The original idea was that the proposed modification of the embedding space could explain naturally phenomena like quantum Hall effect involving fractionization of quantum numbers like spin and charge. This does not however seem to be the case. $G_a \times G_b$ implies just the opposite if these quantum numbers are assigned with the symmetries of the embedding space. For instance, quantization unit for orbital angular momentum becomes n_a where Z_{n_a} is the maximal cyclic subgroup of G_a.

One can however imagine of obtaining fractionization at the level of embedding space for space-time sheets, which are analogous to multi-sheeted Riemann surfaces (say Riemann surfaces associated with $z^{1/n}$ since the rotation by 2π understood as a homotopy of M^4 lifted to the space-time sheet is a non-closed curve. Continuity requirement indeed allows fractionization of the orbital quantum numbers and color in this kind of situation.

3.9.1 Both Covering Spaces And Factor Spaces Are Possible

The observation above stimulates the question whether it might be possible in some sense to replace H or its factors by their multiple coverings.

1. This is certainly not possible for M^4, CP_2, or H since their fundamental groups are trivial. On the other hand, the fixing of 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 a 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. Zero energy ontology forces to modify this picture somewhat. In zero energy ontology causal diamonds (CDs) defined as the intersections of future and past directed light-cones are loci for zero energy states containing positive and negative energy parts of state at the two light-cone boundaries. The location of CD in M^4 is arbitrary but p-adic length scale hypothesis suggests that the temporal distances between tips of CD come as powers of 2 using CP_2 size as unit. Thus M^4 is replaces by CD and $\hat{M}^4$ is replaced with $\hat{CD}$ defined in obvious manner.

3. H_4 represents a straight cosmic string inside CD. Quantum field theory phase corresponds to Jones inclusions with Jones index $\mathcal{M} : \mathcal{N} < 4$. Stringy phase would by previous arguments correspond to $\mathcal{M} : \mathcal{N} = 4$. Also these Jones inclusions are labeled by finite subgroups of $SO(3)$ and thus by Z_n identified as a maximal Abelian subgroup.

   One can argue that cosmic strings are not allowed in QFT phase. This would encourage the replacement $\hat{CD} \times \hat{CP}_2$ implying that surfaces in $CD \times S^2$ and $(M^2 \cap CD) \times CP_2$ are not allowed. In particular, cosmic strings and CP_2 type extremals with M^4 projection in M^2 and thus light-like geodesic without zitterwebegung essential for massivation are forbidden. This brings in mind instability of Higgs=0 phase.

4. The covering spaces in question would correspond to the Cartesian products $\hat{CD}_{n_a} \times \hat{CP}_{2n_b}$ of the covering spaces of $\hat{CD}$ and $\hat{CP}_2$ by Z_{n_a} and Z_{n_b} with fundamental group is $Z_{n_a} \times Z_{n_b}$. One can also consider extension by replacing $M^2 \cap CD$ and S^2 with its orbit under G_a (say tetrahedral, octahedral, or icosahedral group). The resulting space will be denoted by $\hat{CD}\hat{\times}G_a$ *resp.* $\hat{CP}_2\hat{\times}G_b$.

5. One expects the discrete subgroups of $SU(2)$ emerge naturally in this framework if one allows the action of these groups on the singular sub-manifolds $M^2 \cap CD$ 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 $M^2 \cap CD$ 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.

6. Also the orbifolds $\hat{CD}/G_a \times \hat{CP}_2/G_b$ can be allowed as also the spaces $\hat{CD}/G_a \times (\hat{CP}_2\hat{\times}G_b)$ and $(\hat{CD}\hat{\times}G_a) \times \hat{CP}_2/G_b$. Hence the previous framework would generalize considerably by the allowance of both coset spaces and covering spaces.

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 $(M^2 \cap CD) \times CP_2$ takes place? It would seem that the covariant metric of M^4 factor proportional to $\hbar^2$ must be discontinuous at the singular manifold since only in this manner the idea about different scaling factor of M^4 metric can make sense. This is consistent with the identical vanishing of Chern-Simons action in $M^2 \times S^2$.

2. One might worry whether the phase transition changing Planck constant means an instantaneous change of the size of partonic 2-surface in CD degrees of freedom. This is not the case. Light-likeness in $(M^2 \cap CD) \times S^2$ makes sense only for surfaces $X^1 \times D^2 \subset (M^2 \cap CD) \times S^2$, 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 $(M^2 \cap CD) \times S^2$ irrespective of the value of Planck constant requires that X^2 has single point of $(M^2 \cap CD)$ 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) and classical light-like homotopies (cobordisms) are very relevant for the understanding of phase transitions changing Planck constant.

3.9.2 Do Factor Spaces And Coverings Correspond To The Two Kinds Of Jones Inclusions?

What could be the interpretation of these two kinds of spaces?

1. Jones inclusions appear in two varieties corresponding to $\mathcal{M} : \mathcal{N} < 4$ and $\mathcal{M} : \mathcal{N} = 4$ and one can assign a hierarchy of subgroups of $SU(2)$ with both of them. In particular, their maximal Abelian subgroups Z_n label these inclusions. The interpretation of Z_n as invariance group is natural for $\mathcal{M} : \mathcal{N} < 4$ and it naturally corresponds to the coset spaces. For $\mathcal{M} : \mathcal{N} = 4$ the interpretation of Z_n has remained open. Obviously the interpretation of Z_n as the homology group defining covering would be natural.

2. $\mathcal{M} : \mathcal{N} = 4$ should correspond to the allowance of cosmic strings and other analogous objects. Does the introduction of the covering spaces bring in cosmic strings in some controlled manner? Formally the subgroup of $SU(2)$ defining the inclusion is $SU(2)$ would mean that states are $SU(2)$ singlets which is something non-physical. For covering spaces one would however obtain the degrees of freedom associated with the discrete fiber and the degrees of freedom in question would not disappear completely and would be characterized by the discrete subgroup of $SU(2)$.

   For anyons the non-trivial homotopy of plane brings in non-trivial connection with a flat curvature and the non-trivial dynamics of topological QFTs. Also now one might expect similar non-trivial contribution to appear in the spinor connection of $\hat{CD}\hat{\times}G_a$ and $\hat{CP}_2\hat{\times}G_b$. In conformal field theory models non-trivial monodromy would correspond to the presence of punctures in plane.

3. For factor spaces the unit for quantum numbers like orbital angular momentum is multiplied by n_a *resp.* n_b and for coverings it is divided by this number. These two kind of spaces are in a well defined sense obtained by multiplying and dividing the factors of $\hat{H}$ by G_a *resp.* G_b and multiplication and division are expected to relate to Jones inclusions with $\mathcal{M} : \mathcal{N} < 4$ and $\mathcal{M} : \mathcal{N} = 4$, which both are labeled by a subset of discrete subgroups of SU(2).

4. The discrete subgroups of $SU(2)$ with fixed quantization axes possess a well defined multiplication with product defined as the group generated by forming all possible products of group elements as elements of $SU(2)$. This product is commutative and all elements are idempotent and thus analogous to projectors. Trivial group G_1, two-element group G_2 consisting of reflection and identity, the cyclic groups Z_p, p prime, and tetrahedral, octahedral, and icosahedral groups are the generators of this algebra.

By commutativity one can regard this algebra as an 11-dimensional module having natural numbers as coefficients ("rig"). The trivial group G_1, two-element group G_2¡ generated by reflection, and tetrahedral, octahedral, and icosahedral groups define 5 generating elements for this algebra. The products of groups other than trivial group define 10 units for this algebra so that there are 11 units altogether. The groups Z_p generate a structure analogous to natural numbers acting as analog of coefficients of this structure. Clearly, one has effectively 11-dimensional

commutative algebra in 1-1 correspondence with the 11-dimensional "half-lattice" N^{11} (N denotes natural numbers). Leaving away reflections, one obtains N^7. The projector representation suggests a connection with Jones inclusions. An interesting question concerns the possible Jones inclusions assignable to the subgroups containing infinitely manner elements. Reader has of course already asked whether dimensions 11, 7 and their difference 4 might relate somehow to the mathematical structures of M-theory with 7 compactified dimensions. One could introduce generalized WCW spinor fields in the WCW labelled by sectors of H with given quantization axes. By introducing Fourier transform in N^{11} one would formally obtain an infinite-component field in 11-D space.

The question how do the Planck constants associated with factors and coverings relate is far from trivial and I have considered several options.

1. 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 metric allowed by Weyl invariance of Kähler action by dividing metric with $\hbar^2(CP_2)$, one obtains $r^2 \equiv \hbar^2/\hbar_0^2\hbar^2(M^4)/\hbar^2(CP_2)$. This puts M^4 and CP_2 in a very symmetric role and allows much more flexibility in the identification of symmetries associated with large Planck constant phases.

2. Algebraist would argue that Planck constant 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. This gives two options.

3. Option I: $r(X) = n$ for covering and $r(X) = 1/n$ for factor space gives $r \equiv \hbar/\hbar_0 = r(M^4)/r(CP_2)$. This gives $r = n_a/n_b$ for $\hat{H}/G_a \times G_b$ option and $r = n_b/n_a$ for $\hat{H}\hat{times}(G_a \times G_b)$ option with obvious formulas for hybrid cases.

4. Option II: $r(X) = 1/n$ for covering and $r(X) = n$ for factor space gives $r = r(CP_2)/r(M^4)$. This gives $r = n_b/n_a$ for $\hat{H}/G_a \times G_b$ option and $r = n_a/n_b$ for $\hat{H}\hat{times}(G_a \times G_b)$ option with obvious formulas for the hybrid cases.

5. At quantum level the fractionization would come from the modification of fermionic anticommutation (bosonic commutation) relations involving $\hbar$ at the right hand side so that particle number becomes a multiple of $1/n$ or n. If one postulates that the total number states is invariant in the transition, the increase in the number of sheets is compensated by the increase of the fundamental phase space volume proportional to $\hbar$. This would give $r(X) \to r(X)/n$ for factor space and $r(X) \to nr(X)$ for the covering space to compensate the n-fold reduction/increase of states. This would favor Option II.

6. The second manner to distinguish between these two options is to apply the theory to concrete physical situations. Since G_a and G_b act as symmetries in CD and CP_2 degrees of freedom, one might of being able to distinguish between the two options if it is possible to distinguish between the action of G as symmetry of quantum states associated with covering and factor space. Also the quantization of the orbital spin quantum number at single particle level as multiples of n can be distinguished from that in multiples of $1/n$.

3.9.3 A Simple Model Of Fractional Quantum Hall Effect

The generalization of the embedding space suggests that it could possible to understand fractional quantum Hall effect [D1] at the level of basic quantum TGD. This section represents the first rough model of QHE constructed for a couple of years ago is discussed. Needless to emphasize, the model represents only the basic idea and involves ad hoc assumption about charge fractionization.

Recall that the formula for the quantized Hall conductance is given by

$$\begin{aligned} \sigma &= \nu \times \frac{e^2}{h} \ , \\ \nu &= \frac{n}{m} \ . \end{aligned} \tag{3.9.1}$$

Series of fractions in $\nu = 1/3, 2/5, 3/7, 4/9, 5/11, 6/13, 7/15...$, $2/3, 3/5, 4/7, 5/9, 6/11, 7/13...$, $5/3, 8/5, 11/7, 14/9...4/3, 7/5$ $1/5, 2/9, 3/13...$, $2/7, 3/11...$, $1/7....$ with odd denominator have been observed as are also $\nu = 1/2$ and $\nu = 5/2$ states with even denominator [D1].

The model of Laughlin [D13] cannot explain all aspects of FQHE. The best existing model proposed originally by Jain is based on composite fermions resulting as bound states of electron and even number of magnetic flux quanta [D9]. Electrons remain integer charged but due to the effective magnetic field electrons appear to have fractional charges. Composite fermion picture predicts all the observed fractions and also their relative intensities and the order in which they appear as the quality of sample improves.

The generalization of the notion of embedding space suggests the possibility to interpret these states in terms of fractionized charge, spin, and electron number. There are four combinations of covering and factors spaces of CP_2 and three of them can lead to the increase of Planck constant. Besides this there are two options for the formula of Planck constant so that which the very meager theoretical background one can make only guesses. On the following just for fun consideration option I is considered although the conservation of number of states in the phase transition changing $\hbar$ favors option II.

1. The easiest manner to understand the observed fractions is by assuming that both M^4 and CP_2 correspond to covering spaces so that both spin and electric charge and fermion number are fractionized. This means that e in electronic charge density is replaced with fractional charge. Quantized magnetic flux is proportional to e and the question is whether also here fractional charge appears. Assume that this does not occur.

2. With this assumption the expression for the Planck constant becomes for Option II as $r = \hbar/\hbar_0 = n_a/n_b$ and charge and spin units are equal to $1/n_b$ and $1/n_a$ respectively. This gives $\nu = nn_a/n_b$. The values $m = 2, 3, 5, 7, ..$ are observed. Planck constant can have arbitrarily large values. There are general arguments stating that also spin is fractionized in FQHE.

3. The appearance of $\nu = 5/2$ has been observed [D7]. The fractionized charge is $e/4$ in this case. Since $n_i > 3$ holds true if coverings are correlates for Jones inclusions, this requires to $n_b = 4$ and $n_a = 10$. n_b predicting a correct fractionization of charge. The alternative option would be $n_b = 2$ that also Z_2 would appear as the fundamental group of the covering space. Filling fraction $1/2$ corresponds in the composite fermion model and also experimentally to the limit of zero magnetic field [D9]. $n_b = 2$ is however inconsistent with the observed fractionization of electric charge and with the vision inspired by Jones inclusions.

4. A possible problematic aspect of the TGD based model is the experimental absence of even values of n_b except $n_b = 2$ (Laughlin's model predicts only odd values of n). A possible explanation is that by some symmetry condition possibly related to fermionic statistics (as in Laughlin model) n_a/n_b must reduce to a rational with an odd denominator for $n_b > 2$. In other words, one has $n_a \propto 2^r$, where 2^r the largest power of 2 divisor of n_b.

5. Large values of n_a emerge as B increases. This can be understood from flux quantization. One has $e \int BdS = n\hbar(M^4) = nn_a\hbar_0$. By using actual fractional charge $e_F = e/n_b$ in the flux factor would give $e_F \int BdS = n(n_a/n_b)\hbar_0 = n\hbar$. The interpretation is that each of the n_a sheets contributes one unit to the flux for e. Note that the value of magnetic field in given sheet is not affected so that the build-up of multiple covering seems to keep magnetic field strength below critical value.

6. The understanding of the thermal stability is not trivial. The original FQHE was observed in 80 mK temperature corresponding roughly to a thermal energy of $T \sim 10^{-5}$ eV. For graphene the effect is observed at room temperature. Cyclotron energy for electron is (from $f_e = 6 \times 10^5$ Hz at $B = .2$ Gauss) of order thermal energy at room temperature in a magnetic field varying in the range 1-10 Tesla. This raises the question why the original FQHE requires so low temperature. The magnetic energy of a flux tube of length L is by flux quantization roughly $e^2B^2S \sim E_c(e)m_eL$ ($\hbar_0 = c = 1$) and exceeds cyclotron roughly by a factor L/L_e, L_e electron Compton length so that thermal stability of magnetic flux quanta is not the explanation. A possible explanation is that since FQHE involves several values of Planck constant, it is quantum critical phenomenon and is characterized by a critical temperature. The differences of the energies associated with the phase with ordinary Planck constant and phases with different Planck constant would characterize the transition temperature.

As already noticed, it is possible to imagine several other options and the identification of charge unit is rather ad hoc. Therefore this model can be taken only as a warm-up exercise. In [K73] Quantum Hall effect and charge fractionization are discussed in detail and one ends up with a rather detailed view about the delicacies of the Kähler structure of generalized embedding space.

Chapter 4

DNA as Topological Quantum Computer

4.1 Introduction

Large values of Planck constant makes possible all kinds of quantum computations [B5, B47, B13, B46]. What makes topological quantum computation (TQC) [B24, B44, B37, B29, B8] so attractive is that the computational operations are very robust and there are hopes that external perturbations do not spoil the quantum coherence in this case. The basic problem is how to create, detect, and control the dark matter with large $\hbar$. The natural looking strategy would be to assume that living matter, say a system consisting of DNA and cell membranes, performs TQC and to look for consequences.

There are many questions. How the TQC could be performed? Does TQC hypothesis might allow to understand the structure of living cell at a deeper level? What does this hypothesis predict about DNA itself? One of the challenges is to fuse the vision about living system as a conscious hologram with the DNA as TQC vision. The experimental findings of Peter Gariaev [I86, I108] might provide a breakthrough in this respect. In particular, the very simple experiment in which one irradiates DNA sample using ordinary light in UV-IR range and photographs the scattered light seems to allow an interpretation as providing a photograph of magnetic flux tubes containing dark matter. If this is really the case, then the bottle neck problem of how to make dark matter visible and how to manipulate it would have been resolved in principle. The experiment of Gariaev and collaborators [I108] also show that the photographs are obtained only in the presence of DNA sample. This leaves open the question whether the magnetic flux tubes associated with instruments are there in absence of DNA and only made visible by DNA or generated by the presence of DNA.

4.1.1 Basic Ideas Of TQC

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

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

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

In TGD framework TQC differs somewhat from the ordinary one.

1. Zero energy ontology (ZEO) means that physical states decompose into pairs of positive and negative energy states at the "upper" and "lower" light-like boundaries boundaries of $CD \times CP_2$, where CD denotes causal diamond identified as the intersection of the future and past directed light-cones (in the sequel CD is used for $CD \times CP_2$ in order to make notations more elegant). Positive and negative energy states have opposite values of conserved quantum numbers. The interpretation is as an event, say particle scattering, in positive energy ontology. The time like entanglement coefficients define S-matrix, or rather M-matrix, and this matrix can be interpreted as coding for physical laws in the structure of physical state as quantum superposition of statements "A implies B" with A and B represented as positive and negative energy parts of quantum state. The halting of topological quantum computation would select this kind of statement.

2. The new view about quantum state as essentially 4-D notion implies that the outcome of TQC is expressed as a four-dimensional pattern at space-time sheet rather than as time=constant final state. All kinds of patterns would provide a representation of this kind. In particular, holograms formed by large $\hbar$ photons emitted by Josephson currents, including EEG as a special case, would define particular kind of representation of outcome.

4.1.2 Identification Of Hardware Of TQC And TQC Programs

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

1. Living cell is an excellent candidate in this respect. The lipid layers of the cell membrane is 2-D liquid crystal and the 2-D motion of lipids would define naturally the braiding if the lipids are connected to DNA nucleotides. This motion might be induced by the self organization patterns of metabolically driven liquid flow in the vicinity of lipid layer both in interior and exterior of cell membrane and thus self-organization patters of the water flow would define the TQC programs.

2. This identification of braiding implies that TQC as dancing pattern is coded automatically to memory in the sense that lipids connected to nucleotides are like dancers whose feet are connected to the wall of the dancing hall define automatically space-like braiding as the threads connected to their feet get braided. This braiding would define universal memory realized not only as tissue memory but related also to water memory [**?**].

3. It is natural to require that the genetic code is somehow represented as property of braids strands. This is achieved if strands are "colored" so that A,T,C,G correspond to four different "colors". This leads to the hypothesis that flux tubes assignable to nucleotides are wormhole magnetic flux tubes such that the ends of the two sheets carry quark and antiquark (*resp.* antiquark and quark) quantum numbers. This gives mapping A,T,C,G to u, u_c, d, d_c. These quarks are not ordinary quarks but their scaled variants predicted by the fractal hierarchy of color and electro-weak physics. Chiral selection in living matter could be explained by the hierarchy of weak physics. The findings of topologist Barbara Shipman about mathematical structure of honeybee dance led her to proposed that the color symmetries of quarks are in some mysterious way involved with honeybee cognition and this model would justify her intuition [A6].

4. One should identify the representation of qubit. Ordinary spin is not optimal since the representation of 1-gates would require a modification of direction of magnetic field in turn requiring modification of direction of flux tubes. A more elegant representation is based on quark color which means effectively 3-valued logic: true, false, and undefined, also used in ordinary computers and is natural in a situation in which information is only partial. In this case 1-gates would correspond to color rotations for space-time sheets requiring no rotation of the magnetic field.

In this framework genes define the hardware of TQC rather than genetic programs. This means that the evolution takes place also at the level of TQC programs meaning that strict genetic

determinism fails. There are also good reasons to believe that these TQC programs can be inherited to some degree. This could explain the huge differences between us and our cousins in spite of almost the identical genetic codes and explains also cultural evolution and the observation that our children seem to learn more easily those things that we have already learned [I129]. It must be added that DNA as TQC paradigm seems to generalizedDNA, lipids, proteins, water molecules,... can have flux tubes connecting them together and this is enough to generate braidings and TQC programs. Even water could be performing simple TQC or at least building memory representations based on braiding of flux tubes connecting water molecules.

4.1.3 How Much TQC Resembles Ordinary Computation?

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

1. Can one identify program files as space-like braiding patterns. Can one differentiate between program files and data files?

2. In ordinary computers electromagnetic signalling is in key role. The vision about living matter as conscious holograms suggests that this is the case also now. In particular, the idea that entire biosphere forms a TQC web communicating electromagnetically information and control signals looks natural. Topological light rays (MEs) make possible precisely targeted communications with light velocity without any change in pulse shape. Gariaev's findings [I86] that the irradiation of DNA by laser light induces emission of radio wave photons having biological effects on living matter at distances of tens of kilometers supports this kind of picture. Also the model of EEG in which the magnetic body controls the biological body also from astrophysical distances conforms with this picture.

3. The calling of computer programs by simply clicking the icon or typing the name of program followed by return is an extremely economic ways to initiate complex computer programs. This also means that one can construct arbitrarily complex combinations from given basic modules and call this complex by a single name if the modules are able to call each other. This kind of program call mechanism could be realized at the level of TQC by DNA. Since the intronic portion of genome increases with the evolutionary level and is about 98 per cent for humans, one can ask whether introns would contain representations for names of program modules. If so, introns would express themselves electromagnetically by transcribing the nucleotide to a temporal pattern of electromagnetic radiation activating desired subprogram call, presumably the conjugate of intronic portion as DNA sequence. A hierarchical sequence of subprogram calls proceeding downwards at intronic level and eventually activating the TQC program leading to gene expression is suggestive.

   [I86] [I86] has found that laser radiation scattering from given DNA activates only genomes which contain an address coded as temporal pattern for the direction of polarization plane. If flux tubes are super-conducting and there is strong parity breaking (chiral selection) then Faraday rotation for photons traveling through the wormhole flux tube code nucleotide to an angle characterizing the rotation of polarization plane. User id and password would be kind of immune system against externally induced gene expression.

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

4.1.4 Basic Predictions Of DNA As TQC Hypothesis

DNA as TQC hypothesis leads to several testable predictions about DNA itself.

Anomalous em charge

The model for DNA as TQC assigns to flux tubes starting from DNA an anomalous em charge. This means that the total charge of DNA nucleotide using e as unit is $Q = -2 + Q(q)$, where -2 is the charge of phosphate group and $Q(q) = -/+2/3, +/-1/3$ is the electromagnetic charge of quark associated with "upper" sheet of wormhole magnetic flux tube. If the phosphate group is not present one has $Q = Q(q)$. In the presence of phosphate bonds the anomalous charge makes possible the coding of nucleotides to the rotation of angle of polarization plane resulting as photon travels along magnetic flux tube. The anomalous em charge should be visible as an anomalous voltage created by DNA. It would be relatively easy to test this prediction by using various kinds of DNA:s.

Does breaking of matter antimatter and isospin symmetries happen at the level of DNA and mRNA?

The nice feature of the model is that it allows to interpret the slightly broken A-G and T-C symmetries of genetic code with respect to the third nucleotide Z of codon XYZ in terms of the analog of strong isospin symmetry at quark level at wormhole magnetic flux tubes. Also matter-antimatter dichotomy has a chemical analog in the sense that if the letter Y of codon corresponds to quark u, d (antiquark u_c, d_c), the codon codes for hydrophobic (hydrophilic) amino-acid. It is also known that the first letter X of the codon codes for the reaction path leading from a precursor to an amino-acid. These facts play a key role in the model for code of protein folding and catalysis. The basic assumption generalizing base pairing for DNA nucleotides is that wormhole flux tubes can connect an amino-acid inside protein only to molecules (amino-acids, DNA, mRNA, or tRNA) for which Y letter is conjugate to that associated with the amino-acid. This means that the reduction of Planck constant leading to the shortening of the flux tube can bring only these amino-acids together so that only these molecules can find each other in biocatalysis: this would mean kind of code of bio-catalysis.

The fact that matter-antimatter and isospin symmetries are broken in Nature suggests that the same occurs at the level of DNA for quarks and anti-quarks coding for nucleotides. One would expect that genes and other parts of genome differ in the sense that the anomalous em charge, isospin, and net quark number (vanishes for matter antimatter symmetric situation) differ for them. From Wikipedia [I139] one learns that there are rules about distribution of nucleotides which cannot be understood on basis of chemistry. The rules could be understood in terms of new physics. Chargaff's rules state that these symmetries hold true in one per cent approximation at the level of entire chromosomes. Szybalski's rules [I139] state that they fail for genes. There is also a rule stating that in good approximation both strands contain the same portion of DNA transcribed to mRNA. This implies that at mRNA level the sign of matter antimatter asymmetry is always the same: this is analogous to the breaking of matter antimatter asymmetry in cosmology (only matter is observed).

It would be interesting to study systematically the breaking of these symmetries for a sufficiently large sample of genes and also other in parts of genome where a compensating symmetry breaking must occur. That the irradiation of DNA by laser light induces emission of radio wave photons having biological effects on living matter at distances of tens of kilometers supports this kind of picture. Also the model of EEG in which magnetic body controls biological body from astrophysical distances conforms with this picture.

It must be emphasized that this model of DNA as TQC is only one possibility. There is large flexibility concerning the identification of fermions involved. For instance A,T,C,G could be represented also in terms of 4 states assignable to two spin half fermions at parallel flux tubes. This would give rise to high T_c superconductor with both $S = 0$ ($S = 1$) Cooper pairs assignet to flux tubes with opposite (parallel) magnetic fields. The spin-spin interaction energy for the Cooper pair would be negative and proportional to h_{eff} and same for all fermion pairs if $h_{eff} = h_{gr}$ hypothesis holds true at microscopic level.

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` [L19].

4.2 Basic Concepts And Ideas

The following represents a brief overall view about the notions of quantum jump, unitary process described by unitary U-matrix between zero energy states having as its orthogonal rows M-matrices between positive and negative energy parts of zero energy states identifiable as counterpart of ordinary S-matrix and of Negentropy Maximization Principle (NMP) governing the dynamics of state function reduction cascade.

4.2.1 What Happens In Quantum Jump?

Quantum jump involves U process and state function reduction cascade. Negentropy Maximization Principle implies second law for the standard view about state function reduction: second law states that the ensemble entropy increases by the randomness of the outcome of the state function reduction process. When negentropic entanglement possible in what might be called intersection of the real and various p-adic worlds is present the situation is not so clear. Before proceeding to consider the modification of the second law one must define more precisely what U process is.

The simplest view about quantum jump is as a unitary U-process followed by as a cascade of state function reductions proceeding from top to bottom. But what is the top?

1. In positive energy ontology it would be entire Universe. Quantum classical correspondence suggests that one should be able to assign to quantum jump a duration of geometric time. For this proposal this time is most naturally infinite.

2. The vision about fractal hierarchy of selves and quantum jumps together with ZEO suggests a more refined view about quantum jump in which. U-process and subsequent state function reduction cascade could occur independently for disjoint CDs. For a given CD the new sub-CDs (representing mental images of the corresponding self) can be created and old destroyed so that the only constraint would be that only disjoint CDs can perform quantum jumps independently. For this option the duration of geometric time assignable to the quantum jump would naturally correspond to the temporal distance between the tips of CD: p-adic length scale hypothesis and number theoretical vision suggest that this distance comes as an octave of CP_2 time scale (prime or integer multiple is the more general option). For infinitely large CD this would mean infinite duration. This picture is consistent with the TGD view about how the arrow of subjective time induces the arrow of geometric time [K7].

4.2.2 M-Matrix

The unitary U-matrix characterizing the unitary process has as its rows orthogonal M-matrices characterized by in general non-unitarity M-matrices. M-matrix decomposes into a product of positive definite diagonal square roots of density matrix and unitary S-matrix measurement in particle physics experiment. M-matrix represents both the time-like entanglement between positive and negative energy parts of zero energy states with opposite quantum numbers and space-like entanglement for the positive and negative energy states.

Time-like and space-like entanglement in zero energy ontology

M-matrix for each summand is product of Hermitian square root of density matrix and unitary S-matrix multiplied by a square root of probability having interpretation as analog for Boltzmann weight or probability defined by density matrix (note that it is essential to have $Tr(Id) = 1$ for factors of type II_1. If factor of type I_∞ are present situation is more complex. This means that quantum computations are highly universal and M-matrices are characterized by the inclusion $\mathcal{N} \subset \mathcal{M}$ in each summand defining measurement resolution. Hermitian elements of $\mathcal{N}$ act as symmetries of M-matrix. The identification of the reducible entanglement characterized by Boltzmann weight like parameters in terms of thermal equilibrium would allow to interpret quantum theory as square root of thermodynamics.

If the entanglement probabilities defined by S-matrix and assignable to $\mathcal{N}$ rays do not belong to the algebraic extension used then a full state function reduction is prevented by NMP. Ff the generalized Boltzmann weights are also algebraic then also thermal entanglement is irreducible. In

p-adic thermodynamics for Virasoro generator L_0 and using some cutoff for conformal weights the Boltzmann weights are rational numbers expressible using powers of p-adic prime p.

Effects of finite temperature

Usually finite temperature is seen as a problem for quantum computation. In TGD framework the effect of finite temperature is to replace zero energy states formed as pairs of positive and negative energy states with a superposition in which energy varies.

One has an ensemble of space-time sheets which should represent nearly replicas of the quantum computation. There are two cases to be considered.

1. If the thermal entanglement is reducible then each space-time sheet gives outcome corresponding to a well defined energy and one must form an average over these outcomes.

2. If thermal entanglement is irreducible each space-time sheet corresponds to a quantum superposition of space-time sheets, and if the outcome is represented classically as rates and temporal field patterns, it should reflect thermal average of the outcomes as such.

If the degrees of freedom assignable to topological quantum computation do not depend on the energy of the state, thermal width does not affect at all the relevant probabilities. The probabilities are actually affected even in the case of TQC since 1-gates are not purely topological and the effects of temperature in spin degrees of freedom are unavoidable. If T grows the probability distribution for the outcomes flattens and it becomes difficult to select the desired outcome as that appearing with the maximal probability.

4.2.3 About NMP And Quantum Jump

NMP is assumed to be the variational principle telling what can happen in quantum jump and says that the information content of conscious experience for the entire system is maximized. In zero energy ontology (ZEO) the definition of NMP is far from trivial and the recent progress - as I believe - in the understanding of structure of quantum jump forces to check carefully the details related to NMP. A very intimate connection between quantum criticality, life as something in the intersection of realities and p-adicities, hierarchy of effective values of Planck constant, negentropic entanglement (NE), and p-adic view about cognition emerges. One ends up also with an argument why p-adic sector is necessary if one wants to speak about conscious information. I will proceed by making questions.

What happens in single state function reduction?

State function reduction is a measurement of density matrix. The condition that a measurement of density matrix takes place implies standard measurement theory on both real and p-adic sectors: system ends to an *eigen-space* of density matrix. This is true in both real and p-adic sectors. NMP is stronger principle at the real side and implies state function reduction to 1-D subspace - its eigenstate.

The resulting N-dimensional space has however rational entanglement probabilities $p = 1/N$ so that one can say that it is the intersection of realities and p-adicities. If the number theoretic variant of entanglement entropy is used as a measure for the amount of entropy carried by entanglement rather than either entangled system, the state carries genuine information and is stable with respect to NMP if the p-adic prime p divides N. NMP allows only single p-adic prime for real $\rightarrow$ p-adic transition: the power of this prime appears is the largest power of prime appearing in the prime decomposition of N. Degeneracy means also criticality so that ordinary quantum measurement theory for the density matrix favors criticality and NMP fixes the p-adic prime uniquely.

If one - contrary to the above conclusion - assumes that NMP holds true in the entire p-adic sector, NMP gives in p-adic sector rise to a *reduction* of the negentropy in state function reduction if the original situation is negentropic and the eigen-spaces of the density matrix are 1-dimensional. This situation is avoided if one assumes that state function reduction cascade in real or genuinely p-adic sector occurs first (without NMP) and gives therefore rise to N-dimensional eigen spaces. The state is negentropic and stable if the p-adic prime p divides N. Negentropy is generated.

The real state can be transformed to a p-adic one in quantum jump (defining cognitive map) if the entanglement coefficients are rational or belong to an algebraic extension of p-adic numbers in the case that algebraic extension of p-adic numbers is allowed (number theoretic evolution gradually generates them). The density matrix can be expressed as sum of projection operators multiplied by probabilities for the projection to the corresponding sub-spaces. After state function reduction cascade the probabilities are rational numbers of form $p = 1/N$.

Number theoretic entanglement entropy also allows to avoid some objections related to fermionic and bosonic statistics. Fermionic and bosonic statistics require complete anti-symmetrization/symmetriza This implies entanglement which cannot be reduced away. By looking for symmetrized or antisymmetrized 2-particle state consisting of spin 1/2 fermions as the simplest example one finds that the density matrix for either particle is the simply unit 2×2 matrix. This is stable under NMP based on number theoretic negentropy. One expects that the same result holds true in the general case. The interpretation would be that particle symmetrization/antisymmetrization carries negentropy.

The degeneracy of the density matrix is of course not a generic phenomenon and one can argue that it corresponds to some very special kind of physics. The identification of space-time correlates for the hierarchy for the effective values $\hbar_{eff} = n\hbar$ of Planck constant as n-furcations of space-time sheet suggests strongly the identification of this physics in terms of this hierarchy. Hence quantum criticality, the essence of life as something in the rational intersection of realities and p-adicities, the hierarchy of effective values of $\hbar$, negentropic quantum entanglement, and the possibility to make real-p-adic transitions and thus cognition and intentionality would be very intimately related. This is a highly satisfactory outcome, since these ideas have been rather loosely related hitherto.

What happens in quantum jump?

Suppose that everything can be reduced to what happens for a given CD characterized by a scale. There are at least two questions to be answered.

1. There are two processes involved. State function reduction and quantum jump transforming real state to p-adic state (matter to cognition) and vice versa (intention to action). Do these transitions occur independently or not? Does the ordering of the processes matter? It has turned out that the mathematical realization of this picture is very difficult and that these transformations are not even needed in the adelic vision where cognitionandsensory aspects realized as p-adic and real space-time sheets are both present in all scales.

2. State function reduction cascade in turn consists of two different kinds of state function reductions. The M-matrix characterizing the zero energy state is product of square root of density matrix and of unitary S-matrix and the first step means the measurement of the projection operator. It defines a density matrix for both upper and lower boundary of CD and these density matrices are essentially same.

   (a) At the first step a measurement of the density matrix between positive and negative energy parts of the quantum state takes place for CD. One can regard both the lower and upper boundary as an eigenstate of density matrix in absence of NE. The measurement is thus completely symmetric with respect to the boundaries of CDs. At the real sector this leads to a 1-D eigen-space of density matrix if NMP holds true. In the intersection of real and p-adic sectors this need not be the case if the eigenvalues of the density matrix have degeneracy. Zero energy state becomes stable against further state function reductions! The interactions with the external world can of course destroy the stability sooner or later. An interesting question is whether so called higher states of consciousness relate to this kind of states.

   (b) If the first step gave rise to 1-D eigen-space of the density matrix, a state function reduction cascade at either upper of lower boundary of CD proceeding from long to short scales. At given step divides the sub-system into two systems and the sub-system-complement pair which produces maximum negentropy gain is subject to quantum measurement maximizing negentropy gain. The process stops at given subsystem resulting in the process if the resulting eigen-space is 1-D or has NE (p-adic prime p divides the dimension N of eigenspace in the intersection of reality and p-adicity).

4.2.4 Hyper-Finite Factors Of Type II_1 And Quantum Measurement Theory With A Finite Measurement Resolution

The realization that the von Neumann algebra known as hyper-finite factor of type II_1 is tailor made for quantum TGD has led to a considerable progress in the understanding of the mathematical structure of the theory and these algebras provide a justification for several ideas introduced earlier on basis of physical intuition.

Hyper-finite factor of type II_1 has a canonical realization as an infinite-dimensional Clifford algebra and the obvious guess is that it corresponds to the algebra spanned by the gamma matrices of WCW . Also the local Clifford algebra of the embedding space $H = M^4 \times CP_2$ in octonionic representation of gamma matrices of H is important and the entire quantum TGD emerges from the associativity or co-associativity conditions for the sub-algebras of this algebra which are local algebras localized to maximal associative or co-associate sub-manifolds of the embedding space identifiable as space-time surfaces.

The notion of inclusion for hyper-finite factors provides an elegant description for the notion of measurement resolution absent from the standard quantum measurement theory.

1. The included sub-factor creates in zero energy ontology states not distinguishable from the original one and the formally the coset space of factors defining quantum spinor space defines the space of physical states modulo finite measurement resolution.

2. The quantum measurement theory for hyperfinite factors differs from that for factors of type I since it is not possible to localize the state into single ray of state space. Rather, the ray is replaced with the sub-space obtained by the action of the included algebra defining the measurement resolution. The role of complex numbers in standard quantum measurement theory is taken by the non-commutative included algebra so that a non-commutative quantum theory is the outcome.

3. This leads also to the notion of quantum group. For instance, the finite measurement resolution means that the components of spinor do not commute anymore and it is not possible to reduce the state to a precise eigenstate of spin. It is however perform a reduction to an eigenstate of an observable which corresponds to the probability for either spin state.

4. The realization for quantum measurement theory modulo finite measurement resolution is in terms of M-matrices defined in terms of Connes tensor product which essentially means that the included hyper-finite factor N takes the role of complex num bers.

As already explained, the topology of the many-sheeted space-time encourages the generalization of the notion of quantum entanglement in such a way that unentangled systems can possess entangled sub-systems. One can say that the entanglement between sub-selves is not visible in the resolution characterizing selves. This makes possible sharing and fusion of mental images central for TGD inspired theory of consciousness. These concepts find a deeper justification from the quantum measurement theory for hyper-finite factors of type II_1 for which the finite measurement resolution is basic notion.

Also the notions of resolution and monitoring pop up naturally in this framework. p-Adic probabilities relate very naturally to hyper-finite factors of type II_1 and extend the expressive power of the ordinary probability theory. p-Adic thermodynamics with conformal cutoff is very natural for hyper-finite factors of type II_1 and explains p-adic length scale hypothesis $p \simeq 2^k$, k prime characterizing exponentially smaller p-adic length scale.

4.2.5 NMP And Biology

The notion of self is crucial for the understanding of bio-systems and consciousness. It seems that the negentropic entanglement (see **Fig.** `http://tgdtheory.fi/appfigures/cat.jpg` or **Fig. ??** in the appendix of this book) is the decisive element of life and that one can say that in metaphorical sense life resides in the intersection of real and p-adic worlds.

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 and state preparation for next quantum jump is state reduction for the previous quantum jump. In zero energy ontology one can interpret the state preparation for positive and negative energy parts of the state as reduction and preparation in the sense of standard physics. Each self measurement means a decomposition of the sub-system involved to two unentangled parts unless the system is bound state. The decomposition is fixed highly uniquely from the requirement that the reduction of the entanglement entropy is maximal.

Bound state entanglement is stable against self measurement simply because energy conservation prevents the decay to a pair of free (uncorrelated) subsystems. The generalized definition of entanglement entropy allows to assign a negative value of entanglement entropy to rational and algebraic entanglement, so that this kind of entanglement would actually carry information, in fact conscious information (experience of understanding). This kind of entanglement cannot be reduced in state function reduction. Macro-temporal quantum coherence could correspond to a generation of either bound state entanglement or negentropic entanglement, and is indeed crucial for ability to have long lasting non-entropic mental images. Generation of negentropic entanglement would involve experience about expansion of consciousness and that of bound states entanglement a loss of consciousness.

The mathematical models for quantum computers typically operate with systems for which entanglement probabilities are identical. Also rational numbers are involved. Does this mean that negentropic entanglement makes possible quantum computation? This does not seem to be the case. State function reduction with random outcomes is a central element of quantum computation which suggests that quantum computation must be based on entropic entanglement with large enough value of $\hbar$ to overcome the restrictions caused by the interactions with the external world. The negentropic entanglement in turn would relate to conscious information processing involving experience of understanding represented by negentropic entanglement. Negentropic entanglement would make possible conscious cellular automaton type information processing much closer to that carried out by ordinary computers and this information processing might be equally important in living systems.

Life as islands of rational/algebraic numbers in the seas of real and p-adic continua?

NMP and negentropic entanglement demanding entanglement probabilities which are equal to inverse of integer, is the starting point. Rational and even algebraic entanglement coefficients make sense in the intersection of real and p-adic words, which suggests that in some sense life and conscious intelligence reside in the intersection of the real and p-adic worlds.

What could be this intersection of realities and p-adicities?

1. The facts that fermionic oscillator operators are correlates for Boolean cognition and that induced spinor fields are restricted to string world sheets and partonic 2-surfaces suggests that the intersection consists of these 2-surfaces.

2. Strong form of holography allows a rather elegant adelization of TGD by a construction of space-time surfaces by algebraic continuations of these 2-surfaces defined by parameters in algebraic extension of rationals inducing that for various p-adic number fields to real or p-adic number fields. Scattering amplitudes could be defined also by a similar algebraic contination. By conformal invariance the conformal moduli characterizing the 2-surfaces would defined the parameters.

This suggests a rather concrete view about the fundamental quantum correlates of life and intelligence.

1. For the minimal option life would be effectively 2-dimensional phenomenon and essentially a boundary phenomenon as also number theoretical criticality suggests. There are good reasons to expect that only the data from the intersection of real and p-adic string world

sheets partonic two-surfaces appears in U-matrix so that the data localizable to strings connecting partonic 2-surfaces would dictate the scattering amplitudes.

A good guess is that algebraic entanglement is essential for quantum computation, which therefore might correspond to a conscious process. Hence cognition could be seen as a quantum computation like process, a more appropriate term being quantum problem solving [K3]. Living-dead dichotomy could correspond to rational-irrational or to algebraic-transcendental dichotomy: this at least when life is interpreted as intelligent life. Life would in a well defined sense correspond to islands of rationality/algebraicity in the seas of real and p-adic continua. Life as a critical phenomenon in the number theoretical sense would be one aspect of quantum criticality of TGD Universe besides the criticality of the space-time dynamics and the criticality with respect to phase transitions changing the value of Planck constant and other more familiar criticalities. How closely these criticalities relate remains an open question [K85].

The view about the crucial role of rational and algebraic numbers as far as intelligent life is considered, could have been guessed on very general grounds from the analogy with the orbits of a dynamical system. Rational numbers allow a predictable periodic decimal/pinary expansion and are analogous to one-dimensional periodic orbits. Algebraic numbers are related to rationals by a finite number of algebraic operations and are intermediate between periodic and chaotic orbits allowing an interpretation as an element in an algebraic extension of any p-adic number field. The projections of the orbit to various coordinate directions of the algebraic extension represent now periodic orbits. The decimal/pinary expansions of transcendentals are un-predictable being analogous to chaotic orbits. The special role of rational and algebraic numbers was realized already by Pythagoras, and the fact that the ratios for the frequencies of the musical scale are rationals supports the special nature of rational and algebraic numbers. The special nature of the Golden Mean, which involves $\sqrt{5}$, conforms the view that algebraic numbers rather than only rationals are essential for life.

Later progress in understanding of quantum TGD allows to refine and simplify this view dramatically. The idea about p-adic-to-real transition for space-time sheets as a correlate for the transformation of intention to action has turned out to be un-necessary and also hard to realize mathematically. In adelic vision real and p-adic numbers are aspects of existence in all length scales and mean that cognition is present at all levels rather than emerging. Intentions have interpretation in terms of state function reductions in ZEO and there is no need to identify p-adic space-time sheets as their correlates.

That only algebraic extensions are possible is of course only a working hypothesis. Also finite-dimensional extensions of p-adic numbers involving transcendentals are possible and might in fact be necessary. Consider for instance the extension containing $e, e^2, .., e^{p-1}$ as units (e^p is ordinary p-adic number. Infinite number of analogous finite-dimensional extensions can be constructed by taking a function of integer variable such that $f(p)$ exists both p-adically and as a real transcendental number. The powers of $f(p)^{1/n}$ for a fixed value of n define a finite-dimensional transcendental extension of p-adic numbers if the roots do not exist p-adically.

Numbers like $log(p)$ and π cannot belong to a finite-dimensional extension of p-adic numbers [K41]. One cannot of course take any strong attitude concerning the possibility of infinite-dimensional extensions of p-adic numbers but the working hypothesis has been that they are absent. The phases $exp(i2\pi/n)$ define finite dimensional extensions allowing to replace the notion of angle in finite measurement resolution with the corresponding phase factors in finite measurement. The functions $exp(i2\pi q/n)$, where q is arbitrary p-adic integers define in a natural manner the physical counterparts of plane waves and angular momentum eigenstates not allowing an identification as ordinary p-adic exponential functions. They are clearly strictly periodic functions of q with a finite value set. If n is divisible by a power of p, these functions are continuous since the values of the function for q and $q + kp^n$ are identical for large enough values of n. This condition is essential and means in the case of plane waves that the size scale of a system (say one-dimensional box) is multiple of a power of p.

Evolution and second law

Evolution has many facets in TGD framework.

1. A natural characterization of evolution is in terms of p-adic topology relating naturally to cognition. p-Adic primes near powers of two are favored if CDs have the proposed discrete size spectrum. From the point of view of self this would be essentially cosmic expansion in discrete jumps. CDs and can be characterized by powers of 2 and if partonic 2-surfaces correspond to effective p-adic p-adic topology characterized by a power of two, one obtains the commeasurability of the secondary p-adic time scale of particle and that of CD in good approximation.

2. The notion of infinite primes motivates the hypothesis that the many-sheeted structure of space-time can be coded by infinite primes [K94]. The number of primes larger than given infinite prime P is infinitely larger than the number of primes than P. The infinite prime P characterizing the entire universe decomposes in a well defined manner to finite primes and p-adic evolution at the level of entire universe is implied by local p-adic evolution at the level of selves. Therefore maximum entanglement negentropy gain for p-adic self increases at least as $log(p)$ with p in the long run. This kind of relationship might hold true for real selves of p-adic physics is physics of cognitive representations of real physics as suggested by the success of p-adic mass calculations. Thus it should be possible to assign definite p-adic prime to each partonic 2-surface.

3. A further aspect of evolution relates to the hierarchy of Planck constants implying that at dark matter levels rational or at least integer multiples of the favored p-adic time scales are realized. The latter option is favored by the idea that the book like structure with pages consisting of many-sheeted coverings of CD and CP_2, and correlates with the emergence of algebraic extensions of p-adic numbers defined by the roots $exp(i2\pi/n)$ of unity. For the latter option evolution by quantum jumps would automatically imply the drifting of the partonic 2-surfaces to the pages of books labelled by increasing values of Planck constant. For more general option one might argue that drifting to pages with small values of Planck constant is also possible. This would give kind of antizooms of long length scale physics to short scales. Both kind of temporal zooms could be crucial for conscious intelligence building scaled models about time evolution in various scales.

4. The generation of negentropic entanglement between different number fields would of course be the fundamental aspect of evolution. It would give rise to increasingly complex and negentropic sensory perceptions and cognitive representations based on conscious rules coded by negentropic entanglement. This would justify the association concept as it used in neuro-science. Negentropic entanglement could be also crucial for the basic mechanism of metabolism and make possible conscious co-operation even in nano-scales.

Just for fun one can play also with numbers.

1. The highest dark matter level associated with self corresponds to its geometric duration which can be arbitrarily long: the typical duration of the memory span gives an idea about the level of dark matter hierarchy involved if one assumes that the time scale.1 seconds assignable to electrons is the fundamental time scale. If the time scale T of human life cycle corresponds to a secondary p-adic time scale then $T = 100$ years gives the rough estimate $r \equiv \hbar/\hbar_0 = 2^{33}$ if this time scale corresponds to that for dark electron. The corresponding primary p-adic time length scale corresponds to $k = 160$ and is 2.2×10^{-7} meters.

2. If human time scale -taken to be $T = 100$ years- corresponds to primary p-adic time scale of electron, one must have roughly $r = 2^{97}$.

I have already discussed the second law in TGD framework and it seems that its applies only when the time scale of perception is longer than the time scale characterizing the level of the p-adic and dark matter hierarchy. Second law as it is usually stated can be seen as an unavoidable implication of the materialistic ontology.

Stable entanglement and quantum metabolism as different sides of the same coin

The notion of binding has two meanings. Binding as a formation of bound state and binding as a fusion of mental images to larger ones essential for the functioning of brain and regarded as one the big problems of consciousness theory.

Only bound state entanglement and negentropic entanglement are stable against the state reduction process. Hence the fusion of the mental images implies the formation of a bound entropic state- in this case the two interpretations of binding are equivalent- or a negentropic state, which need not be bound state.

1. In the case of negentropic entanglement bound state need not be formed and the interesting possibility is that the negentropic entanglement could give rise to stable states without binding energy. This could allow to understand the mysterious high energy phosphate bond to which metabolic energy is assigned in ATP molecule containing three phosphates and liberated as ATP decays to ADP and phosphate molecule. Negentropic entanglement could also explain the stability of DNA and other highly charged biopolymers. In this framework the liberation of metabolic (negentropic) energy would involve dropping of electrons to a larger space-time sheets accompanying the process $ATP \to ADP + P_i$. A detailed model of this process is discussed in [**?**].

   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.

2. The formation of bound state entanglement is expected to involve a liberation of the binding energy and this energy might be a usable energy. This process could perhaps be coined as quantum metabolism and one could say that quantum metabolism and formation of bound states are different sides of the same coin. It is known that an intense neural activity, although it is accompanied by an enhanced blood flow to the region surrounding the neural activity, does not involve an enhanced oxidative metabolism [J24] (that is $ATP \to ADP$ process and its reversal). A possible explanation is that quantum metabolism accompanying the binding is involved. Note that the bound state is sooner or later destroyed by the thermal noise so that this mechanism would in a rather clever manner utilize thermal energy by applying what might be called buy now–pay later principle.

If these interpretations are correct, there would be two modes of metabolism corresponding to two different kinds of fusion of mental images.

4.2.6 Generalization Of Thermodynamics Allowing Negentropic Entanglement And A Model For Conscious Information Processing

The possibility of negetropic entanglement in TGD framework means that the second law of thermodynamics must be modified. The most obvious modification means only the replacement $S \to S - N$, where S is thermodynamical entropy and N the negentropy associated with negentropic entanglement. Hence the basic formulas of thermodynamics remain formally as such. The generalization leads to a thermodynamical model for how conscious information is generated and how metabolism relates to this. One can also understand why living matter is so effective entropy producer as compared to inanimate matter and the characteristic decomposition of living systems to highly negentropic and entropic parts.

A pessimistic modification of thermodynamics to take into account negentropic entanglement

What does the presence of the negentropic entanglement mean from the point of view of thermodynamics? There are two obvious options to consider. The optimistic option is just the standard thermodynamics saying nothing about negentropy generation. Indeed, number theoretic entanglement negentropy characterizes information carried by entanglement rather than ignorance about individual entangled state and is therefore not identifiable as thermodynamics entropy. The pessimistic option is that the generation of negentropy must be accompanied by a generation of at

least the same amount of entropy: the good news is that this entropy can be carried by different system and it is possible to have genuinely negentropic systems.

The following consideration is restricted to the pessimistic option. Some-one might argue that this provides a more realistic view about the world we live in. One must however remember that evolution is an empirical fact as also dark matter about which we know practically nothing. Furthermore, I am unable to image a concrete mechanism guaranteeing that the generation of negentropic entanglement would be accompanied by a generation of ensemble entropy. The two negentropies are indeed different although there exists a connection. A large degeneracy of states to the geometric realization of $h_{eff} = nh$ hierarchy, implies a large thermodynamical entropy. It also makes possible negentropic entanglement with large number theoretical entanglement negentropy. Therefore large entropic resources implied degeneracy of states can be transformed to large negentropic resources by NMP. Dirt can be transformed to jewels (by love for which negentropic entanglement could serve as a quantum correlate!).

Second ZEO based prediction is that the arrow of thermodynamical time defined by the asymmetry between positive and negative energy parts of zero energy states alternates. There is evidence for this kind of alternation and this lead Fantappie to introduce the notion of syntropy long time ago [J30]. This aspect is not considered in the sequel.

1. One must generalize the basic expression for energy differential

$$dE \quad = \quad TdS - dW \rightarrow T(dS - dN) - dW \quad . \tag{4.2.1}$$

This means that there are two kinds of energies given out by the system. The useful work dW and negentropic energy TdN. For steam engine only dW is present. For ideal system only negentropic energy would be present.

2. What happens to the second law? The pessimistic guess is that generation of negentropy requires a generation of at least same amount of entropy so that one would have

$$\Delta S - \Delta N \geq \quad 0 \quad . \tag{4.2.2}$$

Here S can be interpreted as a sum of two terms. The first part corresponds to the ensemble entropy generated by the randomness of ordinary quantum jumps, and second part to the entropy assignable as maximal entanglement entropy assignable to the decompositions of bound state to two parts. N corresponds to maximal negentropy for the decompositions of negentropic sub-system to pairs. One can criticize these definitions and a possible modification of could be as as the average for the entanglement entropies over this kind of decompositions.

3. Quite generally, Clausius inequality allowing to deduce extremization conditions for various thermodynamical potentials generalizes to

$$T_0(\Delta S - \Delta N) - \Delta E - P_0 \Delta V \quad \geq \quad 0 \quad . \tag{4.2.3}$$

where T_0 and P_0 and temperature and pressure of heat bath. Living systems would be entropy producers and this seems to conform with what we see around us.

For instance, for a system in constant volume one would have

$$\Delta S - \Delta N - \frac{\Delta E}{T} \quad \geq \quad 0 \quad . \tag{4.2.4}$$

so that systems developing negentropy would also generate thermodynamics entropy. For a system in heat bath one has $T = T_0$ and Clausius inequality gives

$$\Delta F = -\Delta W \tag{4.2.5}$$

stating that increase of free energy at constant temperature requires work done on the system ($dW < 0$): otherwise $\Delta F \leq 0$ holds true.

By using the variable $S - N$ instead of S all formulas reduce formally to standard thermodynamics except that S can be negative.

The analog of Carnot cycle as a simple model for information processing in living matter

Carnot engine transforms heat to work. Costa de Beauregard [J15], [J15] has proposed a modification of Carnot engine as a model for information processing. One can consider Carnot engine and its information theoretic analog in this framework.

1. The basic equation for Carnot engine is

$$dW = dQ_{in} - dQ_{out} \geq 0 \ . \tag{4.2.6}$$

Optimal efficiency corresponds to $dS_{out} = dS_{in}$.

2. The information theoretic analog of Carnot engine proposed by Beauregard does not perform work and one would have

$$dW = 0 \ , \tag{4.2.7}$$

and

$$dN = dS_{out} - dS_{in} \geq 0 \ . \tag{4.2.8}$$

The interpretation would be that incoming entropy flow leaves the computer in a state of higher entropy and the difference corresponds to information dN fed to say printer. The increase of entropy would have interpretation in terms of erasing of data from computer memory.

The problematic aspect of the model is that it requires $T_{in} > T_{out}$ in order to have $dN > 0$. For living systems one has however typically $T_{in} < T_{out}$. Already for $T_{in} = T_{out}$ the situation trivializes since one has

$$dN = 0 \tag{4.2.9}$$

by $dW = 0$ and $dS = dQ/T$.

3. In the recent case however a more general condition

$$T_{in}d(S_{in} - N_{in}) - T_{out}d(S_{out} - N_{out}) \quad \geq \quad 0 \tag{4.2.10}$$

holds true and allows to generate conscious information provided it is compensated by thermodynamical entropy. Note that the temperature of the environment can be even lower than the temperatures of the system.

It is also possible to transform information to work as the expression for the differential $dF = -SdT - TdN - dW$ of the generalized free energy $E = E - TS$ shows. The increase of dW for the work done by the system is compensated by the reduction of information dN so that system loses negentropy in the process keeping dF constant. The loss of negentropy couild be interpreted in terms of a loss of metabolic energy which corresponds to negentropic entanglement for AMP, ADP, and ATP molecules.

Basic biological implications

Some clarifying comments about biological implications are in order.

1. There is no need to restrict the consideration to equilibrium systems. First of all, the environment and living system are in general at different temperatures and temperature difference is typically of wrong sign for the model of Beauregard to work in this context. Beauregard's model is of course a model for computation, not for the generation of negentropic mental images. Maybe cognitive machine might be proper term for what the modified model could describe.

2. Quite generally, self-organization requires a feed of energy to the system so that one has flow equilibrium. In the case of living system this feed of energy is metabolic energy associated with the negentropic entanglement transferred to the system in the ATP-ADP process. Self-organization driven by negentropic entanglement leads to standardized negentropic mental images automatically as asymptotic self-organization patterns in 4-D sense (CDs within CDs within... : CD denotes causal diamond defined as cartesian produc to the intersection of the future and past directed light-cones with CP_2, which is the key notion in zero energy ontology).

3. No explicit assumptions about computational aspects of the process has been made. Just a generation of conscious information identified in terms of negentropic entanglement is assumed. The basic character quantum jump as U-process followed by the cascade of state function reductions represents a fractal hierarchy of what can be seen as quantum computations and are distinguished from classical computations in that the process proceeds from top to bottom rather than being a local process. The result of computation is represented using statistical ensembles defined by sub-CDs at various levels of the hierarchy and is in principle communicable by classical fields (say EEG patterns in the case of brain) to higher levels of self hierarchy which in turn can induces the same distributions so that communication of the objective aspects of the experience with the mediation of "medium" is possible. The presence of the "medium" seems unavoidable. Magnetic body would be this medium in TGD inspired biology.

Living matter involves also another aspect made possible by the generalized second law obtained by the replacement $S \to S - N$. Subsystem can have also negative net entropy and split to two highly negentropic and entropic pieces. In the extreme situation this is nothing but excretion, which is absolutely essential element of being alive but sometimes forgotten from the lists of properties distinguishing living matter from inanimate matter. It is not at all clear whether this is possible for standard non-equilibrium systems defining information as a reduction of disorder. At all levels of the fractal hierarchy division into negentropic and entropic subsystems is expected.

This picture seems to be in accordance with basic chemistry of energy metabolism.

1. The process creating both negentropy and entropy would be standardized in living matter and mean a generation of high energy phosphate bonds assignable to AMP, ADP, and ATP containing 1, 2, and 3 phosphates respectively besides the sugar residue. Sugar residue is basic nutrient and would provide the stored metabolic energy transformed to the negentropic energy of the high energy phosphate bonds if the proposed view is correct. Also other DNA nucleotides such as G can appear besides A but in metabolism A has a preferred role.

2. The basic metabolic cycle provides ADP with an additional phosphate energizing it to ATP and the reverse process transfers the metabolic energy and also negentropic entanglement to the acceptor molecule. Also ADP can provide metabolic energy by transforming to AMP when ATP is not available in sufficient amounts. That the catabolism of AMP creates urea excreted out of the system fits with the general picture. The catabolism for nutrients would create the entropy compensating for the negentropy of the high energy phosphate bonds.

3. The backbone of DNA is made of sugar and phosphate residues and corresponds to a sequence of XMP, $X = A, T, C, G$ with each XMP presumably containing single high energy phosphate bond serving as a storage or potential source of negentropy. This conforms with the view that DNA carries conscious information.

Negentropic and entropic entanglement are assumed to generate mental images with opposite emotional colors. This connects information processing with emotions. From neuroscience point of view this is not a news: peptides are molecules of emotions on one hand and molecules of information on the other hand [J11]. The well-known specialization of the left and right hand sides of the amygdala to experience positive and negatively colored emotions could be seen as one instance of this connection and representing also an example about fractal negentropic-entropic differentiation.

4.3 How Quantum Computation In TGD Universe Differs From Standard Quantum Computation?

Many problems of quantum computation in standard sense might relate to a wrong view about quantum theory. If TGD Universe is the physical universe, the situation would improve in many respects. There is the new fractal view about quantum jump and observer as "self" ; there is p-adic length scale hierarchy and hierarchy of Planck constants as well as self hierarchy; there is a new view about entanglement and the possibility of irreducible entanglement carrying genuine information and making possible quantum superposition of fractal quantum computations and quantum parallel dissipation; there is zero energy ontology, the notion of M-matrix allowing to understand quantum theory as a square root of thermodynamics, the notion of measurement resolution allowing to identify M-matrix in terms of Connes tensor product; there is also the notion of magnetic body providing one promising realization for braids in TQC, etc... This section gives a short summary of these aspects of TGD.

There is also a second motivation for this section. Quantum TGD and TGD inspired theory of consciousness involve quite a bundle of new ideas and the continual checking of internal consistency by writing it through again and again is of utmost importance. This section can be also seen as this kind of checking. I can only represent apologies to the benevolent reader: this is a work in rapid progress.

4.3.1 General Ideas Related To Topological Quantum Computation

Topological computation relies heavily on the representation of TQC program as a braiding. There are many kinds of braidings. Number theoretic braids are defined by the orbits of minima of vacuum expectation of Higgs at light-like partonic 3-surfaces (and also at space-like 3-surfaces). There are braidings defined by Kähler gauge potential (possibly equivalent with number theoretic ones) and by Kähler magnetic field. Magnetic flux tubes and partonic 2-surfaces interpreted as strands of define braidings whose strands are not infinitely thin. A very concrete and very complex time-like braiding is defined by the motions of people at the surface of globe: perhaps this sometimes

purposeless-looking fuss has a deeper purpose: maybe those at the higher levels of dark matter hierarchy are using us to carry out complex topological quantum computations)!

General vision about quantum computation

In TGD Universe the hierarchy of Planck constants gives excellent prerequisites for all kinds of quantum computations. The general vision about quantum computation (TQC) would result as a special case and would look like follows.

1. Time-like entanglement between positive and negative energy parts of zero energy states would define the analogs of qc-programs. Space-like quantum entanglement between ends of strands whose motion defines time-like braids would provide a representation of q-information.

2. Both time- and space-like quantum entanglement would correspond to Connes tensor product expressing the finiteness of the measurement resolution between the states defined at ends of space-like braids whose orbits define time like braiding. The characterization of the measurement resolution would thus define both possible q-data and tq-programs as representations for "laws of physics".

3. The braiding between DNA strands with each nucleotide defining one strand transversal to DNA realized in terms of magnetic flux tubes was my first bet for the representation of space-like braiding in living matter. It turned out that the braiding is more naturally defined by flux tubes connecting nucleotides to the lipids of nuclear-, cell-, and endoplasma membranes. Also braidings between other microtubules and axonal membrane can be considered. The conjectured hierarchy of genomes giving rise to quantum coherent gene expressions in various scales would correspond to computational hierarchy.

About the relation between space-like and time-like number theoretic braidings

The relationship between space- and time-like braidings is interesting and there might be some connections also to 4-D topological gauge theories suggested by geometric Langlands program discussed in the previous posting and also in [K50].

1. The braidings along light-like surfaces modify space-like braiding if the moving ends of the space-like braids at partonic 3-surfaces define time-like braids. From TQC point of view the interpretation would be that TQC program is written to memory represented as the modification of space-like braiding in 1-1 correspondence with the time-like braiding.

2. The orbits of space-like braids define codimension two sub-manifolds of 4-D space-time surface and can become knotted. Presumably time-like braiding gives rise to a non-trivial "2-braid". Could also the "2-braiding" based on this knotting be of importance? Do 2-connections of n-category theorists emerge somehow as auxiliary tools? Could 2-knotting bring additional structure into the topological QFT defined by 1-braidings and Chern-Simons action?

3. The strands of dynamically evolving braids could in principle go through each other so that time evolution can transform braid to a new one also in this manner. This is especially clear from standard representation of knots by their planar projections. The points where intersection occurs correspond to self-intersection points of 2-surface as a sub-manifold of space-time surface. Topological QFT: s are also used to classify intersection numbers of 2-dimensional surfaces understood as homological equivalence classes. Now these intersection points would be associated with "braid cobordism".

Quantum computation as quantum superposition of classical computations?

It is often said that quantum computation is quantum super-position of classical computations. In standard path integral picture this does not make sense since between initial and final states represented by classical fields one has quantum superposition over *all* classical field configurations representing classical computations in very abstract sense. The metaphor is as good as the perturbation theory around the minimum of the classical action is as an approximation.

In TGD framework the classical space-time surface is a preferred extremal of Kähler action so that apart from effects caused by the failure of complete determinism, the metaphor makes sense precisely. Besides this there is of course the computation associated with the spin like degrees of freedom in which one has entanglement and which one cannot describe in this manner.

For TQC a particular classical computation would reduce to the time evolution of braids and would be coded by 2-knot. Classical computation would be coded to the manipulation of the braid. Note that the branching of strands of generalized number theoretical braids has interpretation as classical communication.

The identification of topological quantum states

Quantum states of TQC should correspond to topologically robust degrees of freedom separating neatly from non-topological ones.

1. The generalization of the embedding space inspired by the hierarchy of Planck constants suggests an identification of this kind of states as elements of the group algebra of discrete subgroup of $SO(3)$ associated with the group defining covering of M^4 or CP_2 or both in large $\hbar$ sector. One would have wave functions in the discrete space defined by the homotopy group of the covering transforming according to the representations of the group. This is by definition something robust and separated from non-topological degrees of freedom (standard model quantum numbers). There would be also a direct connection with anyons.

2. An especially interesting group is dodecahedral group corresponding to the minimal quantum phase $q = exp(2\pi/5)$ (Golden Mean) allowing a universal topological quantum computation: this group corresponds to Dynkin diagram for E_8 by the ALE correspondence. Interestingly, neuronal synapses involve clathrin molecules [I12] associated with microtubule ends possessing dodecahedral symmetry.

Some questions

A conjecture inspired by the inclusions of HFFs is that these states can be also regarded as representations of various gauge groups which TGD dynamics is conjectured to be able to mimic so that one might have connection with non-Abelian Chern-Simons theories where topological S-matrix is constructed in terms of path integral over connections: these connections would be only an auxiliary tool in TGD framework.

1. Do these additional degrees of freedom give only rise to topological variants of gauge- and conformal field theories? Note that if the earlier conjecture that entire dynamics of these theories could be mimicked, it would be best to perform TQC at quantum criticality where either M^4 or CP_2 dynamical degrees of freedom or both disappear.

2. Could it be advantageous to perform TQC near quantum criticality? For instance, could one construct magnetic braidings in the visible sector near q-criticality using existing technology and then induce phase transition changing Planck constant by varying some parameter, say temperature.

4.3.2 Fractal Hierarchies

Fractal hierarchies are the essence of TGD. There is hierarchy of space-time sheets labelled by preferred p-adic primes. There is hierarchy of Planck constants reflecting a book like structure of the generalized embedding space and identified in terms of a hierarchy of dark matters. These hierarchies correspond at the level of conscious experience to a hierarchy of conscious entities - selves: self experiences its sub-selves as mental images.

Fractal hierarchies mean completely new element in the model for quantum computation. The decomposition of quantum computation to a fractal hierarchy of quantum computations is one implication of this hierarchy and means that each quantum computation proceeds from longer to shorter time scales $T_n = T_0 2^{-n}$ as a cascade like process such that at each level there is a large number of quantum computations performed with various values of input parameters defined by the output at previous level. Under some additional assumptions to be discussed later this

hierarchy involves at a given level a large number of replicas of a given sub-module of TQC so that the output of single fractal sub-module gives automatically probabilities for various outcomes as required.

4.3.3 Irreducible Entanglement And Possibility Of Quantum Parallel Quantum Computation

The basic distinction from standard measurement theory is irreducible entanglement not reduced in quantum jump. There are two kinds of irreducible entanglement: both are negentropic. First kind of irreducible entanglement corresponds to a density matrix, which is proportional to $n \times n$ unit matrix and is naturally associated with the $h_{eff} = nh$ hierarchy. If the entanglement matrix is unitary, density matrix is proportional to unit matrix. One can consider various restrictions on the unitary matrix and these were already discussed. The assumption that the unitary matrix is representable as TQC with basic gate defined by braiding operation is very natural and gives connection between consciousness and quantum computation.

One can imagine also a second candidate for irreducible entanglement. If the density matrix belongs to an algebraic extension of p-adic numbers, one can assign to it number theoretic negentropy. The diagonalized density matrix can however belong to a higher-dimensional algebraic extension than the matrix elements of the entanglement matrix itself. Does this mean that state function reduction can take place only if it is accompanied by an evolutionary step increasing the dimension of algebraic extension involved?

NMP and the possibility of irreducible entanglement

Negentropy Maximimization Principle (NMP) states that entanglement entropy is minimized in quantum jump. For standard Shannon entropy this would lead to a final state which corresponds to a ray of state space. If entanglement probabilities are rational - or even algebraic - one can replace Shannon entropy with its number theoretic counterpart in which p-adic norm of probability replaces the probability in the argument of logarithm: $log(p_n) \to log(|p_n|_p)$. This entropy can have negative values. It is not quite clear whether prime p should be chosen to maximize the number theoretic negentropy or whether p is the p-adic prime characterizing the light-like partonic 3-surface in question.

Obviously NMP favors generation of irreducible entanglement which however can be reduced in U process. Irreducible entanglement is something completely new and the proposed interpretation is in terms of experience of various kinds of conscious experiences with positive content such as understanding.

Quantum superposition of unitarily evolving quantum states generalizes to a quantum superposition of quantum jump sequences defining dissipative time evolutions. Dissipating quarks inside quantum coherent hadrons would provide a basic example of this kind of situation.

Quantum parallel quantum computations and conscious experience

The combination of quantum parallel quantum jump sequences with the fractal hierarchies of scales implies the possibility of quantum parallel quantum computations. In ordinary quantum computation halting selects single computation but in the recent case arbitrarily large number of computations can be carried out simultaneously at various branches of entangled state. The probability distribution for the outcomes is obtained using only single computation.

One would have quantum superposition of space-time sheets (assignable to the maxima of Kähler function) each representing classically the outcome of a particular computation. Each branch would correspond to its own conscious experience but the entire system would correspond to a self experiencing consciously the outcome of computation as intuitive and holistic understanding, and abstraction. Emotions and emotional intellect could correspond to this kind of non-symbolic representation for the outcome of computation as analogs for collective parameters like temperature and pressure.

Delicacies

There are several delicacies involved.

1. The above argument works for factors of type I. For HFFs of type II_1 the finite measurement resolution characterized in terms of the inclusion $\mathcal{N} \subset \mathcal{M}$ mean is that state function reduction takes place to $\mathcal{N}$-ray. There are good reasons to expect that the notion of number theoretic entanglement negentropy generalizes also to this case. Note that the entanglement associated with $\mathcal{N}$ is below measurement resolution.

2. In TGD inspired theory of consciousness irreducible entanglement makes possible sharing and fusion of mental images. At space-time level the space-time sheets corresponding to selves are disjoint but the space-time sheets topologically condensed at them are joined typically by what I call flux tubes identifiable as braid strands (magnetic flux quanta). In topological computation with finite measurement resolution this kind of entanglement with environment would be below the natural resolution and would not be a problem.

3. State function reduction means quantum jump to an eigen state of density matrix. Suppose that density matrix has rational elements. Number theoretic vision forces to ask whether the quantum jump to eigen state is possible if the eigenvalues of ρ do not belong to the algebraic extension of rationals and p-adic numbers used. If not, then one would have number theoretically irreducible entanglement depending on the algebraic extension used. If the eigenvalues actually define the extension there would be no restrictions: this option is definitely simpler.

4. Fuzzy quantum logic [K110] brings also complications. What happens in the case of quantum spinors that spin ceases to be observable and one cannot reduce the state to spin up or spin down. Rather, one can measure only the eigenvalues for the probability operator for spin up (and thus for spin down) so that one has fuzzy quantum logic characterized by quantum phase. Inclusions of HFFs are characterized by quantum phases and a possible interpretation is that the quantum parallelism related to the finite measurement resolution could give rise to fuzzy qubits. Also the number theoretic quantum parallelism implied by number theoretic NMP could effectively make probabilities as operators. The probabilities for various outcomes would correspond to outcomes of quantum parallel state function reductions.

4.3.4 Possible Problems Related To Quantum Computation

At least following problems are encountered in quantum computation.

1. How to preserve quantum coherence for a long enough time so that unitary evolution can be achieved?

2. The outcome of calculation is always probability distribution: for instance, the output with maximum probability can correspond to the result of computation. The problem is how to replicate the computation to achieve the desired accuracy. Or more precisely, how to produce replicas of the hardware of quantum computer defined in terms of classical physics?

3. How to isolate the quantum computer from the external world during computation and despite this feed in the inputs and extract the outputs?

The notion of coherence region in TGD framework

In standard framework one can speak about coherence in two senses. At the level of Schrödinger amplitudes one speaks about coherence region inside which it makes sense to speak about Schrödinger time evolution. This notion is rather defined.

In TGD framework coherence region is identifiable as a region inside which the Kähler-Dirac equation holds true. Strictly speaking, this region corresponds to a light-like partonic 3-surface whereas 4-D space-time sheet corresponds to coherence region for classical fields. p-Adic length scale hierarchy and hierarchy of Planck constants means that arbitrarily large coherence regions are possible.

The precise definition for the notion of coherence region and the presence of scale hierarchies imply that the coherence in the case of single quantum computation is not a problem in TGD framework. De-coherence time or coherence time correspond to the temporal span of space-time sheet and a hierarchy coming in powers of two for a given value of Planck constant is predicted by

basic quantum TGD. p-Adic length scale hypothesis and favored values of Planck constant would naturally reflect this fundamental fractal hierarchy.

De-coherence of density matrix and replicas of TQC

Second phenomenological description boils down to the assumption that non-diagonal elements of the density matrix in some preferred basis (involving spatial localization of particles) approach to zero. The existence of more or less faithful replicas of space-time sheet in given scale allows to identify the counterpart of this notion in TGD context. De-coherence would mean a loss of information in the averaging of M-matrix and density matrix associated with these space-time sheets.

Topological computations are probabilistic. This means that one has a collection of space-time sheets such that each space-time sheet corresponds to more or less the same TQC and therefore the same M-matrix. If M is too random (in the limits allowed by Connes tensor product), the analog of generalized phase information represented by its "phase" - S-matrix - is useless.

In order to avoid de-coherence in this sense, the space-time sheets must be approximate copies of each other. Almost copies are expected to result by dissipation leading to asymptotic self-organization patterns depending only weakly on initial conditions and having also space-time correlates. Obviously, the role of dissipation in eliminating effects of de-coherence in TQC would be something new. The enormous symmetries of M-matrix, the uniqueness of S-matrix for given resolution and parameters characterizing braiding, fractality, and generalized Bohr orbit property of space-time sheets, plus dissipation give good hopes that almost replicas can be obtained.

Isolation and representations of the outcome of TQC

The interaction with environment makes quantum computation difficult. In the case of topological quantum computation this interaction corresponds to the formation of braid strands connecting the computing space-time sheet with space-time sheets in environment. The environment is four-dimensional in TGD framework and an isolation in time direction might be required. The space-time sheets responsible for replicas of TQC should not be connected by light-like braids strands having time-like projections in M^4.

Length scale hierarchy coming in powers of two and finite measurement resolution might help considerably. Finite measurement resolution means that those strands which connect space-time sheets topologically condensed to the space-time sheets in question do not induce entanglement visible at this level and should not affect TQC in the resolution used.

Hence only the elimination of strands responsible for TQC at given level and connecting computing space-time sheet to space-time sheets at same level in environment is necessary and would require magnetic isolation. Note that super-conductivity might provide this kind of isolation. This kind of elimination could involve the same mechanism as the initiation of TQC which cuts the braid strands so the initiation and isolation might be more or less the same thing.

Strands reconnect after the halting of TQC and would make possible the communication of the outcome of computation along strands by using say em currents in turn generating generalized EEG, nerve pulse patterns, gene expression, etc... halting and initiation could be more or less synonymous with isolation and communication of the outcome of TQC.

How to express the outcome of quantum computation?

The outcome of quantum computation is basically a representation of probabilities for the outcome of TQC. There are two representations for the outcome of TQC. Symbolic representation which quite generally is in terms of probability distributions represented in terms "classical space-time" physics. The rates for various processes having basically interpretation as geometro-temporal densities would represent the probabilities just as in the case of particle physics experiment. For TQC in living matter this would correspond to gene expression, neural firing, EEG patterns, ...

A representation as a conscious experience is another (and actually the ultimate) representation of the outcome. It need not have any symbolic counterpart since it is felt. Intuition, emotions and emotional intelligence would naturally relate to this kind of representation made possible by irreducible entanglement. This representation would be based on fuzzy qubits and would mean

that the outcome would be true or false only with certain probability. This unreliability would be felt consciously.

The proposed model of TQC combined with basic facts about theta waves [J35, J42] to be discussed in the subsection about the role of supra currents in TQC suggests that EEG rhythm (say theta rhythm) and correlated firing patterns correspond to the isolation at the first half period of TQC and random firing at second half period to the sub-sequent TQC: s at shorter time scales coming as negative powers of 2. The fractal hierarchy of time scales would correspond to a hierarchy of frequency scales for generalized EEG and power spectra at these scales would give information about the outcome of TQC. Synchronization would be obviously an essential element in this picture and could be understood in terms of classical dynamics which defines space-time surface as a generalized Bohr orbit.

Tqc would be analogous to the generation of a dynamical hologram or "conscious hologram" [K17]. EEG rhythm would correspond to reference wave generated by magnetic body as control and coordination signal and the contributions of spikes to EEG generated by neurons would correspond to the incoming wave interfering with the reference wave.

How data is fed into submodules of TQC?

Scale hierarchy obviously gives TQC a fractal modular structure and the question is how data is fed to submodules at shorter length scales. There are certainly interactions between different levels of scale hierarchy. The general ideas about master-slave hierarchy assigned with self-organization support the hypothesis that these interactions are directed from longer to shorter scales and have interpretation as a specialization of input data to TQC sub-modules represented by smaller space-time sheets of hierarchy. The call of submodule would occur when the TQC of the calling module halts and the result of computation is expressed as a 4-D pattern. The lower level module would start only after the halting of TQC (with respect to subjective time at least) and the durations of resulting TQC's would come as $T_n = 2^{-n}T_0$ that geometric series of TQC's would become possible. There would be entire family of TQC's at lower level corresponding to different values of input parameters from calling module.

One of the ideas assigned to hyper-computation [B2] is that one can have infinite series of computations with durations comings as negative powers of 2 (Zeno paradox obviously inspires this idea). In TGD framework there can be however only a finite series of these TQC's since CP_2 time scale poses a lower bound for the duration of TQC. One might of course ask whether the spectrum of Planck constant could help in this respect.

The role of dissipation and energy feed

Dissipation plays key role in the theory of self-organizing systems [B4]. Its role is to serve as a Darwinian selector. Without an external energy feed the outcome is a situation in which all organized motions disappear. In presence of energy feed highly unique self-organization patterns depending only very weakly on the initial conditions emerge.

In the case of TQC one function of dissipation would be to drive the braidings to static standard configurations, and perhaps even effectively eliminate fluctuations in non-topological degrees of freedom. Note that magnetic fields are important for 1-gates. Magnetic flux conservation however saves magnetic fields from dissipation.

External energy feed is needed in order to generate new braidings. For the proposed model of cellular TQC the flow of intracellular water induces the braiding and requires energy feed. Also now dissipation would drive this flow to standard patterns coding for TQC programs. Metabolic energy would be also needed in order to control whether lipids can flow or not by generating cis type unsaturated bonds. Obviously, energy flows defining self organization patterns would define TQC programs.

Is it possible to realize arbitrary TQC?

The 4-D spin glass degeneracy of TGD Universe due to the enormous vacuum degeneracy of Kähler action gives good hopes that the classical dynamics for braidings allows to realize every possible TQC program. As a consequence, space-time sheets decompose to maximal non-deterministic

regions representing basic modules of TQC. Similar decomposition takes place at the level of light-like partonic 3-surfaces and means decomposition to 3-D regions inside which conformal invariance eliminates light-like direction as dynamical degree of freedom so that the dynamics is effectively that of 2-dimensional object. Since these 3-D regions behave as independent units as far as longitudinal conformal invariance is considered, one can say that light-like 3-surfaces are 3-dimensional in discretized sense. In fact, for 2-D regions standard conformal invariance implies similar effective reduction to 1-dimensional dynamics realized in terms of a net of strings and means that 2-dimensionality is realized only in discretized sense.

4.3.5 Negentropic Entanglement, NMP, Braiding And TQC

Negentropic entanglement, NMP, braiding and TQC

Negentropic entanglement for which number theoretic entropy characterized by p-adic prime is negative so that entanglement carries information, is in key role in TGD inspired theory of consciousness and quantum biology.

1. The key feature of 2-particle negentropic entanglement (see **Fig.** `http://tgdtheory.fi/appfigures/cat.jpg` or **Fig. ??** in the appendix of this book) is that density matrix is projector and thus proportional to unit matrix so that the assumption that state function reduction corresponds to the measurement of density matrix does not imply state function reduction to one-dimensional sub-space. This special kind of degenerate density matrix emerges naturally for the hierarchy $h_{eff} = n \times h$ interpreted in terms of a hierarchy of dark matter phases. I have already earlier considered explicit realizations of negentropic entanglement assuming that E is invariant under the group of unitary or orthogonal transformations (also subgroups of unitary group can be considered -say symplectic group). One can however consider much more general options and this leads to a connection with topological quantum computation (TQC).

2. Entanglement matrix E equal to $1/\sqrt{n}$ factor times unitary matrix U (as a special case orthogonal matrix O) defines a density matrix given by $\rho = UU^\dagger/n = Id_n/n$, which is group invariant. One has NE respected by state function reduction if NMP is assumed. This would give huge number of negentropically entangled states providing a representation for some unitary group or its subgroup (such as symplectic group). In principle any unitary representation of any Lie group would allow representation in terms of NE. In principle any unitary representation of any Lie group would allow a representation in terms of NE.

3. In physics as generalized number theory vision, a natural condition is that the matrix elements of E belong to the algebraic extension of p-adic numbers used so that discreted algebraic subgroups of unitary or orthogonal group are selected. This realizes evolutionary hierarchy as a hierarchy of p-adic number fields and their algebraic extensions, and one can imagine that evolution of cognition proceeds by the generation of negentropically entangled systems with increasing algebraic dimensions and increasing dimension reflecting itself as an increase of the largest prime power dividing n and defining the p-adic prime in question.

4. One fascinating implication is the ability of TGD Universe to emulate itself like Turing machine: unitary S-matrix codes for scattering amplitudes and therefore for physics and negentropically entangled subsystem could represent sub-matrix for S-matrix as rules representing "the laws of physics" in the approximation that the world corresponds to n-dimension Hilbert space. Also the limit $n \to \infty$ makes sense, especially so in the p-adic context where real infinity can correspond to finite number in the sense of p-adic norm. Here also dimensions n given as products of powers of infinite primes can be formally considered.

   One can consider various restrictions on E.

1. In 2-particle case the stronger condition that E is group invariant implies that unitary matrix is identity matrix apart from an overall phase factor: $U = exp(i\phi)Id$. In orthogonal case the phase factor is ± 1. For n-particle NE one can consider group invariant states by using n-dimensional permutation tensor $\epsilon_{i_1,...i_n}$.

2. One can give up the group invariance of E and consider only the weaker condition that permutation is represented as transposition of entanglement matrix: $C_{ij} \to C_{ij}$. Symmetry/antisymmetry under particle exchange would correspond to $C_{ji} = \epsilon C_{ij}$, $\epsilon = \pm 1$. This would give in orthogonal case $OO^T = O^2 = Id$ and $UU^* = Id$ in unitary case.

   In the unitary case particle exchange could be identified as hermitian conjugation $C_{ij} \to C^*_{ji}$ and one would have $U^2 = Id$. Euclidian gamma matrices γ_i define unitary and hermitian generators of Clifford algebra having dimension 2^{2m} for $n = 2m$ and $n = 2m + 1$. It is relatively easy to verify that the squares of completely anti-symmetrized products of k gamma matrices representing exterior algebra normalized by factor $1/\sqrt{k!}$ are equal to unit matrix. For $k = n$ the anti-symmetrized product gives essentially permutation symbol times the product $\prod_k \gamma_k$. In this manner one can construct entanglement matrices representing negentropic bi-partite entanglement.

3. The possibility of taking tensor products $\epsilon_{ij..k...n}\gamma_i \otimes \gamma_j .. \otimes \gamma_k$ of k gamma matrices means that one can has also co-product of gamma matrices. What is interesting is that quantum groups important in topological quantum computation as well as the Yangian algebra associated with twistor Grassmann approach to scattering amplitudes possess co-algebra structure. TGD leads also to the proposal that this structure plays a central role in the construction of scattering amplitudes. Physically the co-product is time reversal of product representing fusion of particles.

4. One can go even further. In 2-dimensional QFTs braid statistics replaces ordinary statistics. The natural question is what braid statistics could correspond to at the level of NE. Braiding matrix is unitary so that it defines NE. Braiding as a flow replaces the particle exchange and lifts permutation group to braid group serving as its infinite covering.

   The allowed unitary matrices representing braiding in tensor product are constructed using braiding matrix R representing the exchange for two braid strands? The well-known Yang-Baxter equation for R defined in tensor product as an invertible element (`http://tinyurl.com/yax3j6mr`) expresses the associativity of braiding operation. Concretely it states that the two braidings leading from 123 to 321 produce the same result. Entanglement matrices constructed R as basic operation would correspond to unitary matrices providing a representation for braids and each braid would give rise to one particular NE.

   This would give a direct connection with TQC for which the entanglement matrix defines a density matrix proportional to $n \times n$ unit matrix: R defines the basic gate [B37]. Braids would provide a concrete space-time correlate for NE giving rise to "Akashic records". Note that in string theory-GRT framework this old idea of TGD has been recently introduced by Maldacena and Sussking as a proposal that wormholes connecting blackholes provide a description of entanglement.

   I have indeed proposed the interpretation of braidings as fundamental memory representations much before the vision about Akashic records. This kind of entanglement matrix need not represent only time-like entanglement but can be also associated also with space-like entanglement. The connection with braiding matrices supports the view that magnetic flux tubes are carriers of negentropically entangled matter and also suggests that this kind of entanglement between -say- DNA and nuclear or cell membrane gives rise to TQC.

Some comments concerning the covering space degrees of freedom associated with $h_{eff} = n \times h$ viz. ordinary degrees of freedom are in order.

1. Negentropic entanglement with n entangled states would correspond naturally to $h_{eff} = n \times h$ and is assigned with "many-particle" states, which can be localized to the sheets of covering but one cannot exclude similar entanglement in other degrees of freedom. Group invariance leaves only group singlets and states which are not singlets are allowed only in special cases. For instance for $SU(2)$ the state $|j, m\rangle = |1, 0\rangle$ represented as 2-particle state of 2 spin 1/2 particles is negentropically entangled whereas the states $|j, m\rangle = |1, \pm 1\rangle$ are pure.

2. Negentropic entanglement associated with $h_{eff} = n \times h$ could factorize as tensor product from other degrees of freedom. Negentropic entanglement would be localised to the covering

space degrees of freedom but there would be entropic entanglement in the ordinary degrees of freedom - say spin. The large value of h_{eff} would however scale up the quantum coherence time and length also in the ordinary degrees of freedom. For entanglement matrix this would correspond to a direct sum proportional to unitary matrices so that also density matrix would be a direct sum of matrices $p_n E_n = p_n Id_n/n$, $\sum p_n = 1$ correspond ing to various values of "other quantum numbers", and state function reduction could take place to any subspace in the decomposition. Also more general entanglement matrices for which the dimensions of direct summands vary, are possible.

3. One can argue that NMP in form does not allow halting of quantum computation. This is not true. The computation halts but in different manner since negentropic entanglement tends to be generated even for weak form of NMP. Weak form of NMP allows also ordinary state function reduction. State function reduction is not need if NE can be directly experienced and self represents this mental image as a kind of abstraction or rule with the state pairs in the superposition representing the instances of the rule.

   It might be also possible to deduce the structure of negentropically entangled state by an interaction free quantum measurement replacing the state function reduction with "externalised" state function reduction. One could speak of interaction free TQC. This TQC would be reading of "Akashic records".

4. One could also counter argue that NMP allows the transfer of NE from the system so that TQC halts. NMP allows this if some another system receives at least the negentropy contained by NE. The interpretation would be as the increase of information obtained by a conscious observer about the outcome of halted quantum computation.

   Metabolism could quite concretely correspond the transfer of NE associated with the NE between nutrient molecules and some system. This would satisfy the demands of NMP and make possible for the organism to avoid the first state function reduction to the opposite boundary of CD (death) In [K72] it is suggested that this system can be of astrophysical size, say gravitational Mother Gaia with magnetic flux tubes characterized by gravitational Planck constant $\hbar_{gr} = GMm/v_0 = \hbar_{eff} = n \times \hbar$, where v_0 is a parameter with dimensions of velocity. There is experimental evidence for dark matter shell around Earth [K89] and there are highly interesting connection to the hypothesis identifying bio-photons as decay products of dark photons located at magnetic flux tubes and having $h_{eff} = h_{gr}$.

4.4 DNA As Topological Quantum Computer

Braids [A1] code for topological quantum computation. One can imagine many possible identifications of braids but this is not essential for what follows. What is highly non-trivial is that the motion of the ends of strands defines both time-like and space-like braidings with latter defining in a well-defined sense a written version of the TQC program, kind of log file. The manipulation of braids is a central element of TQC and if DNA really performs TQC, the biological unit modifying braidings should be easy to identify. An obvious signature is the 2-dimensional character of this unit.

4.4.1 Conjugate DNA As Performer Of TQC And Lipids As Quantum Dancers

In this section the considerations are restricted to DNA as TQC. It is however quite possible that also RNA and other biomolecules could be involved with TQC like process.

Sharing of labor

The braid strands must begin from DNA double strands. Precisely which part of DNA does perform TQC? Genes? Introns [I29] ? Or could it be conjugate DNA which performs TQC? The function of conjugate DNA has indeed remained a mystery and sharing of labor suggests itself.

Conjugate DNA would do TQC and DNA would "print" the outcome of TQC in terms of RNA yielding amino-acids in the case of exons. RNA could the outcome in the case of introns.

The experience about computers and the general vision provided by TGD suggests that introns could express the outcome of TQC also electromagnetically in terms of standardized field patterns. Also speech would be a form of gene expression. The quantum states braid would entangle with characteristic gene expressions. This hypothesis will be taken as starting point in the following considerations.

Cell membranes as modifiers of braidings defining TQC programs?

The manipulation of braid strands transversal to DNA must take place at 2-D surface. The ends of the space-like braid are dancers whose dancing pattern defines the time-like braid, the running of classical TQC program. Space-like braid represents memory storage and TQC program is automatically written to memory during the TQC. The inner membrane of the nuclear envelope and cell membrane with entire endoplasmic reticulum included are good candidates for dancing hall. The 2-surfaces containing the ends of the hydrophobic ends of lipids could be the parquets and lipids the dancers. This picture seems to make sense.

1. Consider first the anatomy of membranes. Cell membrane [I5] and membranes of nuclear envelope [I42] consist of 2 lipid [I32] layers whose hydrophobic ends point towards interior. There is no water here nor any direct perturbations from the environment or interior milieu of cell. Nuclear envelope consists of two membranes having between them an empty volume of thickness 20-40 nm. The inner membrane consists of two lipid layers like ordinary cell membrane and outer membrane is connected continuously to endoplasmic reticulum [I17], which forms a highly folded cell membrane. Many biologists believe that cell nucleus is a prokaryote, which began to live in symbiosis with a prokaryote defining the cell membrane.

2. What makes dancing possible is that the phospholipid layers of the cell membrane are liquid crystals [D2]: the lipids can move freely in the horizontal direction but not vertically. "Phospho" could relate closely to the metabolic energy needs of dancers. If these lipids are self-organized around braid strands, their dancing patterns along the membrane surface would be an ideal manner to modify braidings since the lipids would have standard positions in a lattice. This would be like dancing on a chessboard. Note that the internal structure of lipid does not matter in this picture since it is braid color dicated by DNA nucleotide which matters. As a matter fact, living matter is full of self-organizing liquid crystals and one can wonder whether the deeper purpose of their life be running and simultaneous documentation of TQC programs?

3. Ordinary computers have an operating system: a collection of standard programs - the system - and similar situation should prevail now. The "printing" of outputs of TQC would represent example of this kind of standard program. This TQC program should not receive any input from the environment of the nucleus and should therefore correspond to braid strands connecting conjugate strand with strand. Braid strands would go only through the inner nuclear membrane and return back and would not be affected much since the volume between inner and outer nuclear membranes is empty. This assumption looks ad hoc but it will be found that the requirement that these programs are inherited as such in the cell replication necessitates this kind of structure (see the section "Cell replication and TQC").

4. The braid strands starting from the conjugate DNA could traverse several time through the highly folded endoplasmic reticulum but without leaving cell interior and return back to nucleus and modify TQC by intracellular input. Braid strands could also traverse the cell membrane and thus receive information about the exterior of cell. Both of these TQC programs could be present also in prokaryotes [I54] but the braid strands would always return back to the DNA, which can be also in another cell. In multicellulars (eukaryotes [I19]) braid strands could continue to another cell and give rise to "social" TQC programs performed by the multicellular organisms. Note that the topological character of braiding does not require isolation of braiding from environment. It might be however advantageous to have some kind of sensory receptors amplifying sensory input to standardized re-braiding patterns. Various receptors in cell membrane would serve this purpose.

5. Braid strands can end up at the parquet defined by ends of the inner phospholipid layer: their distance of inner and outer parquet is few nanometers. They could also extend further.

   (a) If one is interested in connecting cell nucleus to the membrane of another cell, the simpler option is the formation of hole defined by a protein attached to cell membrane. In this case only the environment of the second cell affects the braiding assignable to the first cell nucleus.

   (b) The bi-layered structure of the cell membrane could be essential for the build-up of more complex TQC programs since the strands arriving at two nearby hydrophobic 2-surfaces could combine to form longer strands. The formation of longer strands could mean the fusion of the two nearby hydrophobic two-surfaces in the region considered.

      i. The original naïve idea was that TQC could begin with the cutting of the strands so that non-trivial braiding could be generated via lipid dance and TQC would halt when strands would recombine and define a modified braiding. There are however strong objections about cutting since boundaries are not favored by boundary connections.

      ii. If there is a U-shaped flux tube from interior to the exterior and returning back, reconnection at cell membrane could create two U-shaped loops inside and outside the cell membrane. The U-shaped loop could also correspond make the turn through wormhole contact so that the effective splitting would create two wormhole contacts. The latter option fixes completely DNA TQC option based on quarks and antiquarks. If Cooper pairs of charged spin 1/2 fermions forming four spin states assumed to correspond A, T, C, G the first option is the natural one.

   This would allow to connect cell nucleus and cell membrane to a larger TQC unit and cells to multicellular TQC units so that the modification of TQC programs by feeding the information from the exteriors of cells - essential for the survival of multicellulars - would become possible.

Gene expression and other basic genetic functions from TQC point of view

It is useful to try to imagine how gene expression might relate to the halting of TQC. There are of course myriads of alternatives for detailed realizations, and one can only play with thoughts to build a reasonable guess about what might happen.

1. Qubits for transcription factors and other regulators

Genetics is consistent with the hypothesis that genes correspond to those TQC moduli whose outputs determine whether genes are expressed or not. The naïve first guess would be that the value of single qubit determines whether the gene *is* expressed or not. Next guess replaces "*is* " with "*can be* ".

Indeed, gene expression involves promoters, enhancers and silencers [I55]. Promoters are portions of the genome near genes and recognized by proteins known as transcription factors [I63]. Transcription factors bind to the promoter and recruit RNA polymerase, an enzyme that synthesizes RNA. In prokaryotes RNA polymerase itself acts as the transcription factor. For eukaryotes situation is more complex: at least seven transcription factors are involved with the recruitment of the RNA polymerase II catalyzing the transcription of the messenger RNA. There are also transcription factors for transcription factors and transcription factor for the transcription factor itself.

The implication is that several qubits must have value "Yes" for the actual expression to occur since several transcription factors are involved with the expression of the gene in general. In the simplest situation this would mean that the computation halts to a measurement of single qubit for subset of genes including at least those coding for transcription factors and other regulators of gene expression.

2. Intron-exon qubit

Genes would have very many final states since each nucleotide is expected to correspond to at least single qubit. Without further measurements that state of nucleotides would remain highly

entangled for each gene. Also these other qubits are expected to become increasingly important during evolution.

For instance, eukaryotic gene expression involves a transcription of RNA and splicing out of pieces of RNA which are not translated to amino-acids (introns). Also the notion of gene is known to become increasingly dynamical during the evolution of eukaryotes so that the expressive power of genome increases. A single qubit associated with each codon telling whether it is spliced out or not would allow maximal flexibility. Tqc would define what genes are and the expressive power of genes would be due to the evolution of TQC programs: very much like in the case of ordinary computers. Stopping sign codon and starting codon would automatically tell where the gene begins and ends if the corresponding qubit is "Yes". In this picture the old fashioned static genes of prokaryotes without splicings would correspond to TQC programs for which the portions of genome with a given value of splicing qubit are connected.

3. What about braids between DNA, RNA, tRNA and amino-acids

This simplified picture might have created the impression that amino-acids are quantum outsiders obeying classical bio-chemistry. For instance, transcription factors would in this picture end up to the promoter by a random process and "Print" would only increase the density of the transcription factor. If DNA is able to perform TQC, it would however seem very strange if it would be happy with this rather dull realization of other central functions of the genetic apparatus.

One can indeed consider besides the braids connecting DNA and its conjugate - crucial for the success of replication - also braids connecting DNA to mRNA and other forms of RNA, mRNA to tRNA, and tRNA to amino-acids. These braids would provide the topological realization of the genetic code and would increase dramatically the precision and effectiveness of the transcription and translation if these processes correspond to quantum transitions at the level of dark matter leading more or less deterministically to the desired outcome at the level of visible matter be it formation of DNA doublet strand, of DNA-mRNA association, of mRNA-tRNA association or tRNA-amino-acid association.

For instance, a temporary reduction of the value of Planck constant for these braids would contract these to such a small size that these associations would result with a high probability. The increase of Planck constant for braids could in turn induce the transfer of mRNA from the nucleus, the opening of DNA double strand during transcription and mitosis.

Also DNA-amino-acid braids might be possible in some special cases. The braiding between regions of DNA at which proteins bind could be a completely general phenomenon. In particular, the promoter region of gene could be connected by braids to the transcription factors of the gene and the halting of TQC computation to printing command could induce the reduction of Planck constant for these braids inducing the binding of the transcription factor binds to the promoter region. In a similar manner, the region of DNA at which RNA polymerase binds could be connected by braid strands to the RNA polymerase.

How braid color is represented?

If braid strands carry 4-color (A, T, C, G) then also lipid strands should carry this kind of 4-color. The lipids whose hydrophobic ends can be joined to form longer strand should have same color. This color need not be chemical in TGD Universe.

Only braid strands of the same color can be connected as TQC halts. This poses strong restrictions on the model.

1. Do braid strands appear as patches possessing same color?

Color conservation is achieved if the two lipid layers decompose in a similar manner into regions of fixed color and the 2-D flow is restricted inside this kind of region at both layers. A four-colored map of cell membrane would be in question! Liquid crystal structure [I5] applies only up to length scale of $L(151) = 10$ nm and this suggests that lipid layer decomposes into structural units of size $L(151)$ defining also cell membrane thickness. These regions might correspond to minimal regions of fixed color containing $N \sim 10^2$ lipids.

The controversial notion of lipid raft [I34] was inspired by the immiscibility of ordered and disordered liquid phases in a liquid model of membrane. The organization to connected regions of particular phase could be a phenomenon analogous to a separation of phases in percolation. Many

cell functions implicate the existence of lipid rafts. The size of lipid rafts has remained open and could be anywhere between 1 and 1000 nm. Also the time scale for the existence of a lipid raft is unknown. A line tension between different regions is predicted in hydrodynamical model but not observed. If the decomposition into ordered and disordered phases is time independent, ordered phases could correspond to those involved with TQC and possess a fixed color. If disordered phases contain no braid strands the mixing of different colors is avoided. The problem with this option is that it restricts dramatically the possible braidings.

If one takes this option seriously, the challenge is to make patches and patch color (A, T, C, G) visible. Perhaps one could try to mark regions of portions of lipid layer by some marker to find whether the lipid layer decomposes to non-mixing regions.

Quantum criticality suggests that that the patches of lipid layer have a fractal structure corresponding to a hierarchy of TQC program modules. The hydrodynamics would be thus fractal: patches containing patches.... moving with respect to each other would correspond to braids containing braids containing... such that sub-braids behave as braid strands. In principle this is also a testable prediction.

2. Does braid color corresponds to some chemical property?

The conserved braid color is not necessary for the model but would imply genetic coding of the TQC hardware so that sexual reproduction would induce an evolution of TQC hardware. Braid color would also make the coupling of foreign DNA to the TQC performed by the organism difficult and realize an immune system at the level of quantum information processing.

The conservation of braid color poses however considerable problems. The concentration of braid strands of the same color to patches would guarantee the conservation but would restrict the possible braiding dramatically. A more attractive option is that the strands of same color find each other automatically by energy minimization after the halting of TQC. Electromagnetic Coulomb interaction would be the most natural candidate for the interaction in question. Braid color would define a faithful genetic code at the level of nucleotides. It would induce long range correlation between properties of DNA strand and the dynamics of cell immediately after the halting of TQC.

The idea that color could be a chemical property of phospholipids does not seem plausible. The lipid asymmetry of the inner and outer monolayers excludes the assignment of color to the hydrophilic groups PS, PI, PE, PCh. Fatty acids have $N = 14, ..., 24$ carbon atoms and $N = 16$ and 18 are the most common cases so that one could consider the possibility that the 4 most common feet pairs could correspond to the resulting combinations. It is however extremely difficult to understand how long range correlation between DNA nucleotide and fatty acid pair could be created.

3. Does braid color correspond to neutral quark pairs?

It seems that the color should be a property of the braid strand. In TGD inspired model of high T_c super-conductivity [K19] wormhole contacts having u and $\overline{d}$ and d and $\overline{u}$ quarks at the two wormhole throats feed electron's gauge flux to larger space-time sheet. The long range correlation between electrons of Cooper pairs is created by color confinement for an appropriate scaled up variant of chromo-dynamics which are allowed by TGD. Hence the neutral pairs of colored quarks whose members are located the ends of braid strand acting like color flux tube connecting the nucleotide to the lipid could code DNA color to QCD color.

For the pairs $u\overline{d}$ with net em charge the quark and anti-quark have the same sign of em charge and tend to repel each other. Hence the minimization of electro-magnetic Coulomb energy favors the neutral configurations $u\overline{u}$, $d\overline{d}$ and $u\overline{u}$, and $d\overline{d}$ coding for A, T, C, G in some order.

After the halting of TQC only these pairs would form with a high probability. The reconnection of the strands would mean a formation of a short color flux tube between the strands and the annihilation of quark pair to gluon. Note that single braid strand would connect DNA color and its conjugate rather than identical colors so that braid strands connecting two DNA strands (conjugate strands) should always traverse through an even (odd) number of cell membranes. The only plausible looking option is that nucleotides A, T, G, C are mapped to pairs of quark and anti-quarks at the ends of braid strand. Symmetries pose constraints on this coding.

1. By the basic assumptions charge conjugation must correspond to DNA conjugation so that one A and T would be coded to quark pair, say $q\overline{q}$ and its conjugate $\overline{q}q$. Same for C and G.

2. An additional aesthetically appealing working hypothesis is that *both* A and G with the same number of aromatic cycles (three) correspond to $q\overline{q}$ (or its conjugate).

   This would leave four options:

$$\begin{array}{ll} (A,G) \to (u\overline{u}, d\overline{d}) \ , & (T,C) \to (\overline{u}u, \overline{d}d) \ , \\ (A,G) \to (d\overline{d}, u\overline{u}) \ , & (T,C) \to (\overline{d}d), \overline{u}u) \ , \\ (T,C) \to (u\overline{u}, d\overline{d}) \ , & (A,G) \to (\overline{u}u, \overline{d}d) \ , \\ (T,C) \to (d\overline{d}, u\overline{u}) \ , & (A,G) \to (\overline{d}d), \overline{u}u) \ . \end{array} \tag{4.4.1}$$

   It is an experimental problem to deduce which of these correspondences - if any - is realized.

Some general predictions

During TQC the lipids of the two lipid layers should define independent units of lipid hydrodynamics whereas after halting of TQC they should behave as single dynamical unit. Later it will be found that these two phases should correspond to high T_c superconductivity for electrons (Cooper pairs would bind the lipid pair to form single unit) and its absence. This prediction is testable.

The differentiation of cells should directly correspond to the formation of a mapping of a particular part of genome to cell membrane. For neurons the gene expression is maximal which conforms with the fact that neurons can have very large size. Axon might be also part of the map. Stem cells represent the opposite extreme and in this case minimum amount of genome should be mapped to cell membrane. The prediction is that the evolution of cell should be reflected in the evolution of the genome-membrane map.

Quantitative test for the proposal

There is a simple quantitative test for the proposal. A hierarchy of TQC programs is predicted, which means that the number of lipids in the nuclear inner membrane should be larger or at least of the same order of magnitude that the number of nucleotides. For definiteness take the radius of the lipid molecule to be about 5 Angstroms (probably somewhat too large) and the radius of the nuclear membrane about 2.5 μm.

For our own species the total length of DNA strand is about one meter and there are 30 nucleotides per 10 nm. This gives 6.3×10^7 nucleotides: the number of intronic nucleotides is only by few per cent smaller. The total number of lipids in the nuclear inner membrane is roughly 10^8. The number of lipids is roughly twice the number nucleotides. The number of lipids in the membrane of a large neuron of radius of order 10^{-4} meters is about 10^{11}. The fact that the cell membrane is highly convoluted increases the number of lipids available. Folding would make possible to combine several modules in sequence by the proposed connections between hydrophobic surfaces.

4.4.2 How Quantum States Are Realized?

Quantum states should be assigned to the ends of the braid strands and therefore to the nucleotides of DNA and conjugate DNA. The states should correspond to many-particle states of anyons and fractional electrons and quarks and anti-quarks are the basic candidates.

Anyons represent quantum states

The multi-sheeted character of space-time surface as a 4-surface in a book like structure having as pages covering spaces of the embedding space (very roughly, see the appendix) would imply additional degrees of freedom corresponding to the group algebra of the group $G \supset Z_n$ defining the covering. Especially interesting groups are tetra-hedral, octahedral, and icosahedral groups whose action does not map any plane to itself. Group algebra would give rise to $n(G)$ quantum states. If electrons are labeled by elements of group algebra this gives $2^{n(G)}$-fold additional degeneracy corresponding to many-electron states at sheets of covering. The vacuum state would be excluded so

that $2^{n(G)}-1$ states would result. If only Cooper pairs are allowed one would have $m_n = 2^{n(G)-1}-1$ states.

This picture suggests the fractionization of some fermionic charges such as em charge, spin, and fermion number. This aspect is discussed in detail in the Appendix. Single fermion state would be replaced by a set of states with fractional quantum numbers and one would have an analogy with the full electronic shell of atom in the sense that a state containing maximum number of anyonic fermions with the same spin direction would have the quantum numbers of the ordinary fermion.

One can consider two alternative options.

1. The fractionization of charges inspired the idea that catalytic hot spots correspond to "half" hydrogen bonds containing dark fractionally charged electron meaning that the Fermi sea for electronic anyons is not completely filled [K10]. The formation of hydrogen bond would mean a fusion of "half hydrogen bond" and its conjugate having by definition a compensating fractional charges guaranteeing that the net em charge and electron number of the resulting state are those of the ordinary electron pair and the state is stable as an analog of the full electron shell. Half hydrogen bonds would assign to bio-molecules "names" as sequences of half hydrogen bonds and only molecules whose "names" are conjugates of each other would form stable hydrogen bonded pairs. Therefore symbolic dynamics would enter the biology via bio-catalysis. Concerning quantum computation the problem is that the full shell assigned to hydrogen bond corresponds to only single state and cannot carry information.

2. The assignment of braids and fractionally charged anyonic quarks and anti-quarks would realize very similar symbolic dynamics. One cannot exclude the possibility that leptonic charges fractionize to same values as quark charges.

This suggest the following picture.

1. One could assign the fractional quantum numbers to the quarks and anti-quarks at the ends of the flux tubes defining the braid strands. This hypothesis is consistent with the correspondence between nucleotides and quarks and assigns anyonic quantum states to the ends of the braid. Wormhole magnetic fields would distinguish between matter in vivo and in vitro. This option is certainly favored by Occam's razor in TGD Universe.

2. Hydrogen bonds connect the DNA strands which suggests that fractionally charged quantum states at the ends of braids might be assignable to the ends of hydrogen bonds. The model for plasma electrolysis of Kanarev [L2] leads to a proposal that new physics is involved with hydrogen bonds. The presence of fractionally charged particles at the ends of bond might provide alternative explanation for the electrostatic properties of hydrogen bonds usually explained in terms of a modification electronic charge distribution by donor-acceptor mechanism. There would exists entire hierarchy of hydrogen bonds corresponding to the increasing values of Planck constant. DNA and even hydrogen bonds associated with water might correspond to a larger value of Planck constant for mammals than for bacteria.

3. The model for protein folding code [K5] leads to a cautious conclusion that flux tubes are prerequisites for the formation of hydrogen bonds although not identifiable with them. The model predicts also the existence of long flux tubes between acceptors of hydrogen bonds (such as $O=$, and aromatic rings assignable to DNA nucleotides, amino-acid backbone, phosphates, XYP, $X = A,T,G,C$, $Y = M,D,T$). This hypothesis would allow detailed identification of places to which quantum states are assigned.

Hierarchy of genetic codes defined by Mersenne primes

The model for the hierarchy of genetic codes inspires the question whether the favored values of $n(G)-1$ correspond to Mersenne primes [A2]. **Table 4.1** lists the lowest hierarchies. Most of them are short.

The number of states assignable to M_n is $M_n = 2^n - 1$ which does not correspond to full n bits: the reason is that one of the states is not physically realizable. 2^{n-1} states have interpretation

$\{M_n\}$	$\{n(G)\}$ $\{n_b\}$	
$\{2, 7, 127, 2^{127}-1, ?\}$	$\{4, 8, 128, 2^{127}, ?\}$	$\{2, 6, 126, 2^{126}, ?\}$
$\{5, 31, 2^{31}-1\}$	$\{6, 32, 2^{31}\}$	$\{4, 30, 2^{30}\}$
$\{13, 2^{13}-1\}$	$\{14, 2^{13}\}$	$\{12, 2^{12}\}$
$\{17, 2^{17}-1\}$	$\{18, 2^{17}\}$	$\{16, 2^{16}\}$
$\{19, 2^{19}-1\}$	$\{20, 2^{19}\}$	$\{18, 2^{18}\}$
$\{61, 2^{61}-1\}$	$\{62, 2^{61}\}$	$\{60, 2^{60}\}$
$\{89, 2^{89}-1\}$	$\{90, 2^{89}\}$	$\{88, 2^{88}\}$
$\{107, 2^{107}-1\}$	$\{108, 2^{107}\}$	$\{106, 2^{106}\}$

(4.4.2)

Table 4.1: Hierachies of Mersenne primes

as maximal number of statements consistent with an atomic statement (single bit fixed) and to $n_b = n - 1$ bits. **Table 4.1** lists the values of n_b for Mersenne primes.

Notice that micro-tubules decompose into 13 parallel helices consisting of 13 tubulin dimers. Could these helices with the conformation of the last tubulin dimer serving as a kind of parity bit realize M_{13} code?

There would be a nice connection with the basic phenomenology of ordinary computers. The value of the integer $n-1$ associated with Mersenne primes would be analogous to the number of bits of the basic information unit of processor. During the evolution of PCs it has evolved from 8 to 32 and is also power of 2.

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4.4.3 The Role Of High T_c Superconductivity In TQC

A simple model for braid strands leads to the understanding of how high T_c super conductivity assigned with cell membrane [K35] could relate to TQC. The most plausible identification of braid strands is as magnetic or wormhole magnetic flux tubes consisting of pairs of flux tubes connected by wormhole contacts whose throats carry fermion and anti-fermion such that their rotational motion at least partially generates the antiparallel magnetic fluxes at the two sheets of flux tube. The latter option is favored by the model of TQC but one must of course keep mind open for variants of the model involving only ordinary flux tubes. Both kinds of flux tubes can carry charged particles such as protons, electrons, and biologically important ions as dark matter with large Planck constant and the model for nerve pulse and EEG indeed relies on this assumption [K80].

Currents at space-like braid strands

If space-like braid strands are identified as idealized structures obtained from 3-D tube like structures by replacing them with 1-D strands, one can regard the braiding as a purely geometrical knotting of braid strands.

The simplest realization of the braid strand as magnetic flux tube would be as a hollow cylindrical surface connecting conjugate DNA nucleotide to cell membrane and going through 5- and/or 6- cycles associated with the sugar backbone of conjugate DNA nucleotides. The free electron pairs associated with the aromatic cycles would carry the current creating the magnetic field needed.

For wormhole magnetic flux one would have pair of this kind of hollow cylinders connected by wormhole contacts and carrying opposite magnetic fluxes. In this case the currents created by wormhole contacts would give rise to the antiparallel magnetic fluxes at the space-time sheets of wormhole contact and could serve as controllers of TQC. I have indeed proposed long time ago that so called wormhole Bose-Einstein condensates might be fundamental for the quantum control in living matter [K112]. In this case the presence of supra currents at either sheet would generate asymmetry between the magnetic fluxes.

There are two extreme options for both kinds of magnetic fields. For B-option magnetic field is parallel to the strand and vector potential rotates around it. For A-option vector potential is parallel to the strand and magnetic field rotates around it. The general case corresponds to the hybrid of these options and involves helical magnetic field, vector potential, and current.

1. For B-option current flowing around the cylindrical tube in the transversal direction would generate the magnetic field. The splitting of the flux tube would require that magnetic flux vanishes requiring that the current should go to zero in the process. This would make possible selection of a part of DNA strand participating to TQC.

2. For A-option the magnetic field lines of the braid would rotate around the cylinder. This kind of field is created by a current in the direction of cylinder. In the beginning of TQC the strand would split and the current of electron pairs would stop flowing and the magnetic field would disappear. Also now the initiation of computation would require stopping of the current and should be made selectively at DNA.

   The control of the TQC should rely on currents of electron pairs (perhaps Cooper pairs) associated with the braid strands. Supra currents would have quantized values and they are therefore very attractive candidates. The (supra) currents could also bind lipids to pairs so that they would define single dynamical unit in 2-D hydrodynamical flow. One can also think that Cooper pairs with electrons assignable to different members of lipid pair bind it to a single dynamical unit.

Do supra currents generate magnetic fields?

Energetic considerations favor the possibility that supra currents create the magnetic fields associated with the braid strands defined by magnetic flux tubes. In the case of wormhole magnetic flux tubes supra currents could generate additional magnetic fields present only at the second sheet of the flux tube.

Supra current would be created by a voltage pulse ΔV, which gives rise to a constant supra current after it has ceased. Supra current would be destroyed by a voltage pulse of opposite sign. Therefore voltage pulses could define an elegant fundamental control mechanism allowing to select the parts of genome participating to TQC. This kind of voltage pulse could be collectively initiated at cell membrane or at DNA. Note that constant voltage gives rise to an oscillating supra current.

Josephson current through the cell membrane would be also responsible for dark Josephson radiation determining that part of EEG which corresponds to the correlate of neuronal activity [K35] . Note that TGD predicts a fractal hierarchy of EEGs and that ordinary EEG is only one level in this hierarchy. The pulse initiating or stopping TQC would correspond in EEG to a phase shift by a constant amount

$$\Delta\Phi = Ze\Delta VT/\hbar \ ,$$

where T is the duration of pulse and ΔV its magnitude.

The contribution of Josephson current to EEG responsible for beta and theta bands interpreted as satellites of alpha band should be absent during TQC and only EEG rhythm would be present. The periods dominated by EEG rhythm should be observed as EEG correlates for problem solving situations (say mouse in a maze) presumably involving TQC. The dominance of slow EEG rhythms during sleep and meditation would have interpretation in terms of TQC.

Topological considerations

The existence of supra current requires that the flow allows for a complex phase $exp(i\Psi)$ such that supra current is proportional to $\nabla\Psi$. This requires integrability in the sense that one can assign to the flow lines of A or B (combination of them in the case of A-B braid) a coordinate variable Ψ varying along the flow lines. In the case of a general vector field X this requires $\nabla\Psi = \Phi X$ giving $\nabla \times X = -\nabla\Phi/\Phi$ as an integrability condition. This condition defines what is known as Beltrami flow [K15].

The perturbation of the flux tube, which spoils integrability in a region covering the entire cross section of flux tube means either the loss of super-conductivity or the disappearance of the

net supra current. In the case of the A-braid, the topological mechanism causing this is the increase in the dimension of the CP_2 projection of the flux tube so that it becomes 3-D [K15], where I have also considered the possibility that 3-D character of CP_2 projection is what transforms the living matter to a spin glass type phase in which very complex self-organization patterns emerge. This would conform with the idea that in TQC takes place in this phase.

Fractal memory storage and TQC

If Josephson current through cell membrane ceases during TQC, TQC manifests itself as the presence of only EEG rhythm characterized by an appropriate cyclotron frequency. Synchronous neuron firing might therefore relate to TQC. The original idea that a phase shift of EEG is induced by the voltage initiating TQC - although wrong - was however useful in that it inspired the question whether the initiation of TQC could have something to do with what is known as a place coding by phase shifts performed by hippocampal pyramidal cells [J35, J42]. The playing with this idea provides important insights about the construction of quantum memories and demonstrates the amazing explanatory power of the paradigm once again.

The model also makes explicit important conceptual differences between TQC a la TGD and in the ordinary sense of wordin particular those related to different view about the relation between subjective and geometric time.

1. In TGD TQC corresponds to the unitary process U taking place following by a state function reduction and preparation. It replaces WCW ("world of classical worlds") spinor field with a new one. WCW spinor field represent generalization of time evolution of Schrödinger equation so that a quantum jump occurs between entire time evolutions. Ordinary TQC corresponds to Hamiltonian time development starting at time $t = 0$ and halting at $t = T$ to a state function reduction.

2. In TGD the expression of the result of TQC is essentially 4-D pattern of gene expression (spiking pattern in the recent case). In usual TQC it would be 3-D pattern emerging as the computation halts at time t. Each moment of consciousness can be seen as a process in which a kind of 4-D statue is carved by starting from a rough sketch and proceeding to shorter details and building fractally scaled down variants of the basic pattern. Our life cycle would be a particular example of this process and would be repeated again and again but of course not as an exact copy of the previous one.

1. Empirical findings

The place coding by phase shifts was discovered by O'Reefe and Recce [J35]. In [J42] 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.

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. Yamaguchi and collaborators have also found that the gradual phase shift occurs at half theta

cycle whereas firings at the other half cycle show no correlation [J42] . One should also find an interpretation for this.

2. TGD based interpretation of findings

How this picture relates to TGD based 4-D view about memory in which primary memories are stored in the brain of the geometric past?

1. The simplest option is the initiation of TQC like process in the beginning of each theta cycle of period T and having geometric duration $T/2$. The transition $T \to T/2$ conforms nicely with the fundamental hierarchy of time scales comings as powers defining the hierarchy of measurement resolutions and associated with inclusions of hyperfinite factors of type II_1 [K110]. That firing is random at second half of cycle could simply mean that no TQC is performed and that the second half is used to code the actual events of "geometric now".

2. In accordance with the vision about the hierarchy of Planck constants defining a hierarchy of time scales of long term memories and of planned action, the scaled down variants of memories would be obtained by down-wards scaling of Planck constant for the dark space-time sheet representing the original memory. In principle a scaling by any factor $1/n$ (actually by any rational) is possible and would imply the scaling down of the geometric time span of TQC and of light-like braids. One would have TQC's inside TQC's and braids within braids (flux quanta within flux quanta). The coding of the memories to braidings would be an automatic process as almost so also the formation of their zoomed down variants.

3. A mapping of the time evolution defining memory to a linear array of neurons would take place. This can be understood if the scaled down variant (scaled down value of $\hbar$) of the space-time sheet representing original memory is parallel to the linear neuron array and contains at scaled down time value t_n a stimulus forcing n^{th} neuron to fire. The 4-D character of the expression of the outcome of TQC allows to achieve this automatically without complex program structure.

To sum up, it seems that the scaling of Planck constant of time like braids provides a further fundamental mechanism not present in standard TQC allowing to build fractally scaled down variants of not only memories but TQC's in general. The ability to simulate in shorter time scale is a certainly very important prerequisite of intelligent and planned behavior. This ability has also a space-like counterpart: it will be found that the scaling of Planck constant associated with space-like braids connecting bio-molecules might play a fundamental role in DNA replication, control of transcription by proteins, and translation of mRNA to proteins. A further suggestive conclusion is that the period T associated with a given EEG rhythm defines a sequence of TQC's having geometric span $T/2$ each: the rest of the period would be used to perceive the environment of the geometric now. The fractal hierarchy of EEGs would mean that there are TQC's within TQC's in a very wide range of time scales.

4.4.4 Codes And TQC

TGD suggests the existence of several (genetic) codes besides 3-codon code [K44, **?**]. The experience from ordinary computers and the fact that genes in general do not correspond to $3n$ nucleotides encourages to take this idea more seriously. The use of different codes would allow to tell what kind of information a given piece of DNA strand represents. DNA strand would be like a drawing of building containing figures (3-code) and various kinds of text (other codes). A simple drawing for the building would become a complex manual containing mostly text as the evolution proceeds: for humans 96 per cent of code would corresponds to introns perhaps obeying some other code.

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

The hierarchy of Mersenne primes $M_n = 2^n - 1$ with $M_{n(next)} = M_{M_n}$ starting from $n = 2$ with $M_2 = 3$ gives rise to 1-code with 4 codons, 3-code with 64 codons, and $3 \times 21 = 63$-code with 2^{126} codons [K44] realized as sequences of 63 nucleotides (the length of 63-codon is about $2L(151)$, roughly twice the cell membrane thickness. It is not known whether this Combinatorial Hierarchy continues ad infinitum. Hilbert conjectured that this is the case.

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

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

There are also further short Combinatorial hierarchies corresponding to Mersenne primes [A2].

1. $n = 13$ defines Mersenne prime M_{13}. The code would have $2^{12=6\times 2}$ codons representable as sequences of 6 nucleotides or 2 3-codons. This code might be associated with microtubuli.

2. The Fermat prime $17 = 2^4 + 1$ defines Mersenne prime M_{17} and the code would have $2^{16=8\times 2}$ codons representable as sequences of 8 nucleotides.

3. $n = 19$ defines Mersenne prime M_{19} and code would have $2^{18=9\times 2}$ codons representable as sequences of 9 nucleotides or three DNA codons.

4. The next Mersennes are M_{31} belonging to $n = 5$ hierarchy, M_{61} with $2^{60=30\times 2}$ codons represented by 30-codons. This corresponds to DNA length $L(151) = 10$ nm (cell membrane thickness). M_{89} (44-codons), M_{107} (53-codons) and M_{127} (belonging to the basic hierarchy) are the next Mersennes. Next Mersenne corresponds to M_{521} (260-codon) and to completely super-astrophysical p-adic length scale and might not be present in the hierarchy.

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

4.5 How To Realize The Basic Gates?

In order to have a more concrete view about realization of TQC, one must understand how quantum computation can be reduced to a construction of braidings from fundamental unitary operations. The article "Braiding Operators are Universal Quantum Gates" by Kaufmann and Lomonaco [B37] contains a very lucid summary of how braids can be used in topological quantum computation.

1. The identification of the braiding operator R - a unitary solution of Yang-Baxter equation - as a universal 2-gate is discussed. In the following I sum up only those points which are most relevant for the recent discussion.

2. One can assign to braids both knots and links and the assignment is not unique without additional conditions. The so called braid closure assigns a unique knot to a given braid by connecting n^{th} incoming strand to n^{th} outgoing strand without generating additional knotting. All braids related by so called Markov moves yield the same knot. The Markov trace (q-trace actually) of the unitary braiding S-matrix U is a knot invariant characterizing the braid closure.

3. Braid closure can be mimicked by a topological quantum computation for the original n-braid plus trivial n-braid and this leads to a quantum computation of the modulus of the Markov

trace of U. The probability for the diagonal transition for one particular element of Bell basis (whose states are maximally entangled) gives the modulus squared of the trace. The closure can be mimicked quantum computationally.

4.5.1 Universality Of TQC

Quantum computer is universal if all unitary transformations of n^{th} tensor power of a finite-dimensional state space V can be realized. Universality is achieved by using only two kinds of gates. The gates of first type are single particle gates realizing arbitrary unitary transformation of $U(2)$ in the case of qubits. Only single 2-particle gate is necessary and universality is guaranteed if the corresponding unitary transformation is entangling for some state pair. The standard choice for the 2-gate is CNOT acting on bit pair (t, c). The value of the control bit c remains of course unchanged and the value of the target bit changes for $c = 1$ and remains unchanged for $c = 0$.

4.5.2 The Fundamental Braiding Operation As A Universal 2-Gate

The realization of CNOT or gate equivalent to it is the key problem in topological quantum computation. For instance, the slow de-coherence of photons makes quantum optics a promising approach but the realization of CNOT requires strongly nonlinear optics. The interaction of control and target photon should be such that for second polarization of the control photon target photon changes its direction but keeps it for the second polarization direction.

For braids CNOT can be expressed in terms of the fundamental braiding operation e_n representing the exchange of the strands n and $n+1$ of the braid represented as a unitary matrix R acting on $V_n \otimes V_{n+1}$.

The basic condition on R is Yang-Baxter equation expressing the defining condition $e_n e_{n+1} e_n = e_{n+1} e_n e_{n+1}$ for braid group generators. The solutions of Yang-Baxter equation for spinors are well-known and CNOT can be expressed in the general case as a transformation of form $A_1 \otimes A_2 R A_3 \otimes A_4$ in which single particle operators A_i act on incoming and outgoing lines. 3-braid is the simplest possible braid able to perform interesting TQC, which suggests that genetic codons are associated with 3-braids.

The dance of lipids on chessboard defined by the lipid layer would reduce R to an exchange of neighboring lipids. For instance, the matrix $R = DS$, $D = diag(1, 1, 1, -1)$ and $S = e_{11} + e_{23} + e_{32} + e_{44}$ the swap matrix permuting the neighboring spins satisfies Yang-Baxter equation and is entangling.

4.5.3 What The Replacement Of Linear Braid With Planar Braid Could-Mean?

Standard braids are essentially linear objects in plane. The possibility to perform the basic braiding operation for the nearest neighbors in two different directions must affect the situation somehow.

1. Classically it would seem that the tensor product defined by a linear array must be replaced by a tensor product defined by the lattice defined by lipids. Braid strands would be labelled by two indices and the relations for braid group would be affected in an obvious manner.

2. The fact that DNA is a linear structure would suggests that the situation is actually effectively one-dimensional, and that the points of the lipid layer inherit the linear ordering of nucleotides of DNA strand. One can however ask whether the genuine 2-dimensionality could provide a mathematical realization for possible long range correlations between distant nucleotides n and $n + N$ for some N. p-Adic effective topology for DNA might become manifest via this kind of correlations and would predict that N is power of some prime p which might depend on organism's evolutionary level.

3. Quantum conformal invariance would suggest effective one-dimensionality in the sense that only the observables associated with a suitably chosen linear braid commute. One might also speak about topological quantum computation in a direction transversal to the braid strands giving a slicing of the cell membrane to parallel braid strands. This might mean an additional computational power.

4. Partonic picture would suggest a generalization of the linear braid to a structure consisting of curves defining the decomposition of membrane surface regions such that conformal invariance applies separately in each region: this would mean breaking of conformal invariance and 2-dimensionality in discrete sense. Each region would define a one parameter set of topological quantum computations. These regions might corresponds to genes. If each lipid defines its own conformal patch one would have a planar braid.

4.5.4 Single Particle Gates

The realization of single particle gates as $U(2)$ transformations leads naturally to the extension of the braid group by assigning to the strands sequences of group elements satisfying the group multiplication rules. The group elements associated with a n^{th} strand commute with the generators of braid group which do not act on n^{th} strand. G would be naturally subgroup of the covering group of rotation group acting in spin degrees of spin 1/2 object. Since $U(1)$ transformations generate only an overall phase to the state, the presence of this factor might not be necessary. A possible candidate for $U(1)$ factor is as a rotation induced by a time-like parallel translation defined by the electromagnetic scalar potential $\Phi = A_t$.

One of the challenges is the realization of single particle gates representing $U(2)$ rotation of the qubit. The first thing to come mind was that $U(2)$ corresponds to $U(2)$ rotation induced by magnetic field and electric fields. A more elegant realization is in terms of $SU(3)$ rotation, where $SU(3)$ is color group associated with strong interactions. This looks rather weird but there is direct evidence for the prediction that color $SU(3)$ is associated with TQC and thus cognition: something that does not come first in mind! I have myself written text about the strange finding of topologist Barbara Shipman suggesting that quarks are in some mysterious manner involved with honeybee dance and proposed an interpretation.

The realization of qubit as ordinary spin

A possible realization for single particle gate $s \subset SU(2)$ would be as $SU(2)$ rotation induced by a magnetic pulse. This transformation is fixed by the rotation axis and rotation angle around this axes. This kind of transformation would result by applying to the strand a magnetic pulse with magnetic field in the direction of rotation axes. The duration of the pulse determines the rotation angle. Pulse could be created by bringing a magnetic flux tube to the system, letting it act for the required time, and moving it away. $U(1)$ phase factor could result from the electromagnetic gauge potential as a non-integrable phase factor $exp(ie \int A_t dt/\hbar)$ coming from the presence of scale potential $\Phi = A_t$ in the Hamiltonian.

Conrete model for realization of 1-gates in terms of ordinary rotations

What could be the simplest realization of the $U(2)$ transformation in the case of cell membrane assuming that it corresponds to ordinary rotation?

1. There should be a dark spin 1/2 particle associated with each lipid, electron or proton most plausibly. TGD based model for high T_c superconductivity [K19] predicts that Cooper pairs correspond to pairs of cylindrical space-time sheets with electrons at the two space-time sheets. The size scale of the entire Cooper corresponds to p-adic length scale $L(151)$ defining the thickness of the cell membrane and cylindrical structure to $L(149)$, the thickness of lipid layer so that electrons are the natural candidates for TQC. The Cooper pair BE condensate would fuse the lipid pairs to form particles of lipid liquid.

2. Starting of TQC requires the splitting of electron Cooper pairs and its halting the formation of Cooper pairs again. The initiation of TQC could involve increase of temperature or an introduction of magnetic field destroying the Cooper pairs. Tqc could be also controlled by supra currents flowing along cylindrical flux tubes connecting 5- and/or aromatic cycles of conjugate DNA nucleotides to the cell membrane. The cutting of the current flow would make it possible for braid strand to split and TQC to begin.

3. By shifting a magnetic flux tube or sheet parallel to the cell membrane to the position of the portion of membrane participating to TQC is the simplest manner to achieve this. Halting

could be achieved by removing the flux tube. The unitary rotation induced by the constant background magnetic field would not represent gate and it should be possible to eliminate its effect from TQC proper.

4. The gate would mean the application of a magnetic pulse much stronger than background magnetic field on the braid strands ending at the lipid layer. The model for the communication of sensory data to the magnetic body requires that magnetic flux tubes go through the cell membrane. This would suggest that the direction of the magnetic flux tube is temporarily altered and that the flux tube then covers part of the lipid for the required period of time.

   The realization of the single particle gates requires electromagnetic interactions. That single particle gates are not purely topological transformations could bring in the problems caused by a de-coherence due to electromagnetic perturbations. The large values of Planck constant playing a key role in the TGD based model of living matter could save the situation. The large value of $\hbar$ would be also required by the anyonic character of the system necessary to obtain R-matrix defining a universal 2-gate.

   The minimum time needed to inducing full 2π rotation around the magnetic axes would be essentially the inverse of cyclotron frequency for the particle in question in the magnetic field considered$T = 1/f_c = 2\pi m/ZeB$. For electrons in the dark magnetic field of $B = .2$ Gauss assigned to living matter in the quantum model of EEG this frequency would be about $f_c = .6$ MHz. For protons one would have $f_c = 300$ Hz. For a magnetic field of Tesla the time scales would be reduced by a factor 2×10^{-5}.

The realization of 1-gate in terms of color rotations

One can criticize the model of 1-gates based on ordinary spin. The introduction of magnetic pulses does not look an attractive idea and seems to require additional structures besides magnetic flux tubes (MEs?). It would be much nicer to assign the magnetic field with the flux tubes defining the braid strands. The rotation of magnetic field would however require changing the direction of braid strands. This does not look natural. Could one do without this rotation by identifying spin like degree of freedom in some other manner? This is indeed possible.

TGD predicts a hierarchy of copies of scaled up variants of both weak and color interactions and these play a key role in TGD inspired model of living matter. Both weak isospin and color isospin could be considered as alternatives for the ordinary spin as a realization of qubit in TGD framework. Below color isospin is discussed but one could consider also a realization in terms of nuclei and their exotic counterparts [L2], [L2] differing only by the replacement of neutral color bond between nuclei of nuclear string with a charged one. Charge entanglement between nuclei would guarantee overall charge conservation.

1. Each space-time sheet of braid strands contains quark and antiquark at its ends. Color isospin and hypercharge label their states. Two of the quarks of the color triplet form doublet with respect to color isospin and the third is singlet and has different hyper charge Y. Hence qubit could be realized in terms of color isospin I_3 instead of ordinary spin but third quark would be inert in the Boolean sense. Qubit could be also replaced with qutrit and isospin singlet could be identified as a statement with ill-defined truth value. Trits are used also in ordinary computers. In TGD framework finite measurement resolution implies fuzzy qubits and the third state might relate to this fuzziness. Also Gödelian interpretation can be consideredthe quark state with vanishing isospin would be associated with counterparts of undecidable propositions to which one cannot assign truth value (consider sensory input which is so ambiguous that one cannot tell what is there or a situation in which one cannot decide whether to do something or not). Note that hyper-charge would induce naturally the U(1) factor affecting the over all phase of qubit but affecting differently to the third quark.

2. Magnetic flux tubes are also color magnetic flux tubes carrying non-vanishing classical color gauge field in the case that they are non-vacuum extremals. The holonomy group of classical color field is an Abelian subgroup of the $U(1) \times U(1)$ Cartan subgroup of color group. Classical color magnetic field defines the choice of quantization axes for color quantum numbers. For

instance, magnetic moment is replaced with color magnetic moment and this replacement is in key role in simple model for color magnetic spin spin splittings between spin 0 and 1 mesons as well as spin 1/2 and 3/2 baryons.

3. There is a symmetry breaking of color symmetry to subgroup $U(1)_{I_3} \times U(1)_Y$ and color singletness is in TGD framework replaced by a weaker condition stating that physical states have vanishing net color quantum numbers. This makes possible the measurement of color quantum numbers in the manner similar to that for spin. For instance, color singlet formed by quark and antiquark with opposite color quantum numbers can in the measurement of color quantum numbers of quark reduce to a state in which quark has definite color quantum numbers. This state is a superposition of states with vanishing Y and I_3 in color singlet and color octet representations. Strong form of color confinement would not allow this kind of measurement.

4. Color rotation in general changes the directions of quantization axis of I_3 and Y and generates a new state basis. Since $U(1) \times U(1)$ leaves the state basis invariant, the space defined by the choices of quantization axes is 6-dimensional flag manifold $F = SU(3)/U(1) \times U(1)$. In contrast to standard model, color rotations in general do not leave classical electromagnetic field invariant since classical em field is a superposition of color invariant induced Kähler from and color non-invariant part proportional classical Z^0 field. Hence, although the magnetic flux tube retains its direction and shape in M^4 degrees of freedom, its electromagnetic properties are affected and this is visible at the level of classical electromagnetic interactions.

5. If color isospin defines the qubit or qutrit in topological quantum computation, color quantum numbers and the flag manifold F should have direct relevance for cognition. Amazingly, there is a direct experimental support for this! Years ago topologist Barbara Shipman made the intriguing observation that honeybee dance can be understood in terms of a model involving the flag manifold F [A6]. This led her to propose that quarks are in some mysterious manner involved with the honeybee dance. My proposal [K42] was that color rotations of the space-time sheets associated with neurons represent geometric information: sensory input would be coded to color rotations defining the directions of quantization axes for I_3 and Y. Subsequent state function reduction would provide conscious representations in terms of trits characterizing for instance sensory input symbolically.

   In [K42] I introduced the notions of geometric and sensory qualia corresponding to two choices involved with the quantum measurement: the choice of quantization axes performed by the measurer and the "choice" of final state quantum numbers in state function reduction. In the case of honeybee dance geometric qualia could code information about the position of the food source. The changes of color quantum numbers in quantum jump were identified as visual colors. In state function reduction one cannot speak about change of quantum numbers but about their emergence. Therefore one must distinguish between color qualia and the conscious experience defined by the emergence of color quantum numbers: the latter would have interpretation as qutrit.

Summarizing, this picture suggests that 1-gates of DNA TQC (understood as "dance of lipids") are defined by color rotations of the ends of space-like braid strands and at lipids. The color rotations would be induced by sensory and other inputs to the system. Topological quantum computation would be directly related to conscious experience and sensory and other inputs would fix the directions of the color magnetic fields.

Realization of braid operation in terms of $h_{eff} = n \times h$ hypothesis

This option would realize braiding as an analog for braiding for the degrees of freedom representable in terms of n-fold covering of embedding space (or space-time surfaces). The different branches of covering would relate to the branching of preferred extremal in n-furcation. Simplest n-furcation would corresponds to that resulting when 2π rotated space-time point no more corresponds to the original point (note that analog with Riemann surface associated with $z^{1/n}$. Similar phenomenon is possible in CP_2 degrees of freedom. The vision is that it is possible to construct dark k-particle

states for $k \leq n$ in these discrete degrees of freedom so that discrete variant of second quantization would be in question.

Since large $h_{eff} = nh$ is highly favourable for TQC, the idea that living matter would perform TQC using dark matter phase. This option does not seem to be in conflict with the other option. One can in principle assign to each ordinary quantum state an $h_{eff} = nh$ and even allow the value of n to depend on the ordinary quantum numbers. By NMP state function reduction leads to one of these sub-spaces. As discussed, the outcome of TQC could be deduced by interaction free quantum measurement utilizing "externalized" state function reduction. It is of course not all obvious whether this procedure is equivalent with the standard one. The large value of h_{eff} would increase quantum coherence time and quantum coherence length associated with ordinary quantum numbers so that halting in this sense would be possible.

4.6 About Realization Of Braiding

The most plausible identification of braid strands is as magnetic or wormhole magnetic flux tubes. Flux tubes can contain charged particles such as protons, electrons, and biologically important ions as dark matter with large Planck constant and the model for nerve pulse and EEG indeed relies on this assumption [K80].

4.6.1 Could Braid Strands Be Split And Reconnect All The Time?

As far as braiding alone is considered, braid strands could be split all the time. This would require wormhole flux tubes if strands carry monopole flux. In other words, there would be no continuation of strands through the cell membrane. Computation would halt when lipids lose their unsaturated cis bonds so that they cannot follow the liquid flow. The conservation of strand color would be trivially true but would not have any implications. Supra currents would not be needed to control TQC and there would be no connection with generalized EEG. It is not obvious how the gene expression for the outcome of TQC could take place since the strands would not connect genome to genome. For these reasons this option does not look attractive.

The models for prebiotic evolution [**?**] and protein folding [K5] lead to a suggestion that braids can connect all kind of bio-molecules to each other and also water molecules and bio-molecules. Thus DNA TQC would represent only one example of TQC like activities performed by the living matter. The conclusion is that braidings are dynamical with reconnection of flux tubes representing a fundamental transformation changing the braiding and thus also TQC programs.

4.6.2 What Do Braid Strands Look Like?

In the following the anatomy of braid strands is discussed at general level and then and identification in terms of flux tubes of magnetic body is proposed.

Braid strands as nearly vacuum extremals

The braid strands should be nearly quantum critical sub-manifolds of $M^4 \times CP_2$ so that phase transitions changing Planck constant and thus their length can take place easily (DNA replication, binding of mRNA molecules to DNA during transcription, binding of transcription factors to promoters, binding of tRNA-amino-acid complexes to mRNA...).

Depending on whether phase transition takes place in M^4 or CP_2 degrees of freedom, either their M^4 projection belongs to $M^2 \subset M^4$ or their CP_2 projection to the homological trivial geodesic sphere $S^2 \subset CP_2$. In the latter case a vacuum extremal is in question. Maximal quantum criticality means $X^4 \subset M^2 \times S^2$ so that one has straight string with a vanishing string tension. The almost vacuum extremal property guarantees the braid strands can be easily generated from vacuum.

An additional requirement is that the gravitational mass is small. For objects of type $M^2 \times X^2_g$, $X^2_g \subset E^2 \times CP_2$, the gravitational mass vanishes for $g = 1$ (genus) and is of order CP_2 mass otherwise and negative for $g > 1$. Torus topology is the unique choice. A simple model for the braid strand is as a small non-vacuum deformation of $X^4 = M^2 \times X^2_g \subset M^2 \subset E^2 \times S^2$, $g = 1$. As a special case one has $X^4 = M^2 \times S^1 \times S^1 \subset M^2 \subset E^2 \times S^1$, for which M^4 projection is a

hollow cylinder, which could connect the aromatic 5- or 6-cycle of sugar backbone to another DNA strand, lipid, or amino-acid.

Braid strands as flux tubes of color magnetic body

One can make this model more detailed by feeding in simple physical inputs. The flux tubes carry magnetic field when the supra current is on. In TGD Universe all classical fields are expressible in terms of the four CP_2 coordinates and their gradients so that em, weak, color and gravitational fields are not independent as in standard model framework. In particular, the ordinary classical em field is necessarily accompanied by a classical color field in the case of non-vacuum extremals. This predicts color and ew fields in arbitrary long scales and quantum classical correspondence forces to conclude that there exists fractal hierarchy of electro-weak and color interactions.

Since the classical color gauge field is proportional to Kähler form, its holonomy group is Abelian so that effectively $U(1) \times U(1) \subset SU(3)$ gauge field is in question. The generation of color flux requires colored particles at the ends of color flux tube so that the presence of pairs of quark and antiquark assignable to the pairs of wormhole throats at the ends of the tube is unavoidable if one accepts quantum classical correspondence.

In the case of cell, a highly idealized model for color magnetic flux tubes is as flux tubes of a dipole field. The preferred axis could be determined by the position of the centrosomes forming a T shaped structure. DNA strands would define the idealized dipole creating this field: DNA is indeed negatively charged and electronic currents along DNA could create the magnetic field. The flux tubes of this field would go through nuclear and cell membrane and return back unless they end up to another cell. This is indeed required by the proposed model of TQC.

It has been assumed that the initiation of TQC means that the supra current ceases and induces the splitting of braid strands. The magnetic flux need not however disappear completely. As a matter fact, its presence forced by the conservation of magnetic flux seems to be crucial for the conservation of braiding. Indeed, during TQC magnetic and color magnetic flux could return from lipid to DNA along another space-time sheet at a distance of order CP_2 radius from it. For long time ago I proposed that this kind of structures -which I christened "wormhole magnetic fields" - might play key role in living matter [K112]. The wormhole contacts having quark and antiquark at their opposite throats and coding for A, T, C, G would define the places where the current flows to the "lower" space-time sheet to return back to DNA. Quarks would also generate the remaining magnetic field and supra current could indeed cease.

The fact that classical em fields and thus classical color fields are always present for non-vacuum extremals means that also the motion of any kind of particles (space-time sheets), say water flow, induces a braiding of magnetic flux tubes associated with molecules in water if the temporary splitting of flux tubes is possible. Hence the prerequisites for TQC are met in extremely general situation and TQC involving DNA could have developed from a much simpler form of TQC performed by water giving perhaps rise to what is known as water memory [I65, I66, I82, I83]. This would also suggest that the braiding operation is induced by the a controlled flow of cellular water.

4.6.3 How To Induce The Basic Braiding Operation?

The basic braiding operation requires the exchange of two neighboring lipids. After some basic facts about phospholipids the simplest model found hitherto is discussed.

Some facts about phospholipids

Phospholipids [I46] - which form about 30 per cent of the lipid content of the monolayer - contain phosphate group. The dance of lipids requires metabolic energy and the hydrophilic ends of the phospholipid could provide it. They could also couple the lipids to the flow of water in the vicinity of the lipid monolayer possibly inducing the braiding. Of course, the causal arrow could be also opposite.

The hydrophilic part of the phospholipid is a nitrogen containing alcohol such as serine, inositol or ethanolamine, or an organic compound such as choline. Phospholipids are classified into 3 kinds of phosphoglycerides [I45] and sphingomyelin.

1. Phosphoglycerides

In cell membranes, phosphoglycerides are the more common of the two phospholipids, which suggest that they are involved with TQC. One speaks of phosphotidyl X, where X= serine, inositol, ethanolamine is the nitrogen containing alcohol and X=Ch the organic compound. The shorthand notion OS, PI, PE, PCh is used.

The structure of the phospholipid is most easily explained using the dancer metaphor. The two fatty chains define the hydrophobic feet of the dancer, glycerol and phosphate group define the body providing the energy to the dance, and serine, inositol, ethanolamine or choline define the hydrophilic head of the dancer (perhaps "deciding" the dancing pattern).

There is a lipid asymmetry in the cell membrane. PS, PE, PI in cytoplasmic monolayer (alcohols). PC (organic) and sphingomyelin in outer monolayer. Also glycolipids are found only in the outer monolayer. The asymmetry is due to the manner that the phospholipids are manufactured.

[I44] [I44] in the inner monolayer is negatively charged and its presence is necessary for the normal functioning of the cell membrane. It activates protein kinase C which is associated with memory function. PS slows down cognitive decline in animals models. This encourages to think that the hydrophilic polar end of at least PS is involved with TQC, perhaps to the generation of braiding via the coupling to the hydrodynamic flow of cytoplasm in the vicinity of the inner monolayer.

2. Fatty acids

The fatty acid chains in phospholipids and glycolipids usually contain an even number of carbon atoms, typically between 14 and 24 making 5 possibilities altogether. The 16- and 18-carbon fatty acids are the most common. Fatty acids [I20] may be saturated or unsaturated, with the configuration of the double bonds nearly always cis.

The length and the degree of unsaturation of fatty acids chains have a profound effect on membranes fluidity as unsaturated lipids create a kink, preventing the fatty acids from packing together as tightly, thus decreasing the melting point (increasing the fluidity) of the membrane. The number of unsaturaded cis bonds and their positions besides the number of Carbon atoms characterizes the lipid. Quite generally, there are $3n$ Carbons after each bond. The creation of unsatured bond by removing H atom from the fatty acid could be an initiating step in the basic braiding operation creating room for the dancers. The bond should be created on both neighboring lipids simultaneously.

Could hydrodynamic flow induce braiding operations?

One can imagine several models for what might happen during the braiding operation in the lipid bilayer [I33]. One such view is following.

1. The creation of unsaturated bond and involving elimination of H atom from fatty acid would lead to cis configuration and create the room needed by dancers. This operation should be performed for both lipids participating in the braiding operation. After the braiding it might be necessary to add H atom back to stabilize the situation. The energy needed to perform either or both of these operations could be provided by the phosphate group.

2. The hydrophilic ends of lipids couple the lipids to the surrounding hydrodynamic flow in the case that the lipids are able to move. This coupling could induce the braiding. The primary control of TQC would thus be by using the hydrodynamic flow by generating localized vortices. There is considerable evidence for water memory [I65] but its mechanism remains to be poorly understood. If also water memory is realized in terms of the braid strands connecting fluid particles, DNA TQC could have evolved from water memory.

3. Sol-gel phase transition is conjectured to be important for the quantum information processing of cell [J6]. In the transition which can occur cyclically actin filaments (also at EEG frequencies) are assembled and lead to a gel phase resembling solid. Sol phase could correspond to TQC and gel to the phase following the halting of TQC. Actin filaments might be assignable with braid strands or bundles of them and shield the braiding. Also microtubules might shield bundles of braid strands.

4. Only inner braid strands are directly connected to DNA which also supports the view that only the inner monolayer suffers a braiding operation during TQC and that the outer monolayer should be in a "freezed" state during it. There is a net negative charge associated with the inner mono-layer possibly relating to its participation to the braiding. The vigorous hydrodynamical flows known to take place below the cell membrane could induce the braiding.

4.6.4 Some Qualitative Tests

In life sciences the standard manner to test a model is to look whether the function of the system is affected in the predicted manner if one somehow interferes the system. Now interfering with TQC should affect the gene expression resulting otherwise.

1. Lipid layer hydrodynamics is predicted to allow two fundamental phases. The pairs of lipids should behave like single dynamical unit in super-conducting phase and as independent units in non-super-conducting phase. The application of magnetic field or increase of temperature should induce a transition between these two phases. These phase transitions applied selectively to the regions of cell membrane should affect gene expression. One could prevent halting of TQC by applying an external magnetic field and thus prevent gene expression. One could dream of deducing gene-membrane mapping with endoplasmic reticulum included.

2. The temperature range in which quantum critical high T_c super-conductivity is possible is probably rather narrow and should correspond to the temperature range in which cell membrane is functional. Brain is functional in a very narrow range of temperatures. Selective freezing of cell membrane might provide information about gene map provided by cell membrane.

3. One could do various things to the cell membrane. One could effectively remove part of it, freeze, or heat some part of the lipid liquid and look whether this has effects on gene expression. The known effects of ELF em fields on the behavior and physiology of vertebrates [K35] might relate to the fact that these fields interfere with TQC.

4. Artificially induced braiding by inducing a motion of lipids by some kind of stirring during TQC could induce/affect gene expression.

5. The application of external dark magnetic fields could affect gene expression. Tqc could be initiated artificially in some part of cell membrane by the application of dark magnetic field. Running TQC could be halted by an application of dark magnetic field interfering to zero with the background field. The application of magnetic pulses would affect TQC and thus gene expression. The problem is how to create dark magnetic fields in given length scale (range of magnetic field strength). Perhaps one could generate first ordinary magnetic field and then transform it to dark magnetic field by $\hbar$ changing phase transition. This could be achieved by a variation of some macroscopic parameters such as temperature, magnetic field strength, and analog of doping fraction appearing in standard high T_c super-conductivity.

6. Artificially induced scalings of $\hbar$ by varying temperature and parameters such as pH should induce or stop DNA replication, DNA-mRNA transcription and the translation of mRNA to proteins.

4.7 A Model For Flux Tubes

Biochemistry represents extremely complex and refined choreography. It is hard to believe that this reduces to a mere unconscious and actually apparent fight for chemical survival. In TGD Universe consciousness would be involved even at the molecular level and magnetic body would be the choreographer whose dance would induce the molecular activities. This picture combined with the idea of standard plugs and terminals at which flux tubes end, leads to a to a picture allowing to formulate a model for protein folding.

4.7.1 Flux Tubes As A Correlates For Directed Attention

Molecular survival is the standard candidate for the fundamental variational principle motivating the molecular intentional actions. There is entire hierarchy of selves and the survival at the higher level of hierarchy would force co-operation and altruistic behavior at the lower levels. One might hope that this hypothesis reduces to Negentropy Maximization Principle [K60], which states that the information contents of conscious experience is maximized. If this picture is accepted, the evolution of molecular system becomes analogous to the evolution of a society.

Directed attention is the basic aspect of consciousness and the natural guess would be that directed attention corresponds to the formation of magnetic flux tubes between subject and target. The directedness property requires some manner to order the subject and target.

1. The ordering by the values of Planck constant is what first comes in mind. The larger space-time sheet characterized by a larger value of Planck constant and thus at a higher level of evolutionary hierarchy would direct its attention to the smaller one.

2. Also the ordering by the value of p-adic prime characterizing the size scale of the space-time sheet could be considered but in this case directedness could be questioned.

3. Attention can be directed also to thoughts. Could this mean that attention is directed from real space-time sheets to p-adic space-time sheets for various values of primes but not vice versa? Or could the direction be just the opposite at least in the intentional action transforming p-adic space-time sheet to real space-time sheet? Perhaps directions are opposite for cognition.

The generation of (wormhole) magnetic flux tubes could be the correlate for the directed attention, not only at molecular level, but quite generally. Metaphorically, the strands of braid would be the light rays from the eyes of the perceiver to the target and their braiding would code the motions of the target to a topological quantum computation like activity and form a memory representation at least. The additional aspect of directed attention would be the coloring of the braid strands, kind of coloring for the virtual light rays emerging from the eyes of the molecular observer. In the case of DNA this can induce a coloring of braid strands emerging from amino-acids and other molecules so that it would indeed become possible to assign to free amino-acid the conjugate of the codon XYZ coding for it.

Attention can be also redirected. For this process there is a very nice topological description as a reconnection of flux tubes. What happens is that flux tubes $A \to B$ and $C \to D$ fuse for a moment and become flux tubes $A \to D$ and $C \to B$. This process is possible only if the strands have the same color so that the values of the quark charges associated with A and B are the same.

1. Reconnection process can modify TQC programs. For instance, in the case of the flux tubes coming from nucleotides X and X_c and ending to the lipid layer this process means that X and X_c and corresponding lipids become connected and genome builds memory representation about this process via similar link.

2. Reconnection process makes also possible what might be called color inheritance allowing amino-acids to inherit the conjugate colors of the nucleotides of the codon coding it.

3. DNA would have memory representation about molecular processes via these changing braiding topologies, and one could say that these molecular processes reflect the bodily motions of the magnetic body. Entire molecular dynamics of the organism could represent an enormous TQC induced by the motor activities of the magnetic body. At the level of sensory experience similar idea has been discussed earlier [K97]: out of body experiences (OBEs) and illusions such as train illusion could be understood in terms of motor action of magnetic body inducing virtual sensory percepts.

Attention can be also switched on and off. Here the structure of the lipid ends containing two nearby situated $= O$: s suggest the mechanism: the short flux tube connecting $= O$: s disappears by reconnection mechanism with a pair of hydrogen bonded water molecules leading to a shortcut of the connecting flux tubes to $= O - -H_2O$ hydrogen bonds. The minimization of Coulomb interaction energy at each end implies that re-appearance of the flux tubes creates a short flux tube with the original strand color.

4.7.2 Does Directed Attention Generate Memory Representations And TQC Like Processes

Directed attention induces braiding if the target is moving and changing its shape. This gives rise to a memory representation of the behavior of the object of attention and also to a TQC like process. A considerable generalization of TQC paradigm suggests itself.

Tqc could be induced by the braiding between DNA and lipids, DNA and proteins via folding processes, DNA RNA braiding and braiding between DNA and its conjugate, DNA and protein braiding. The outcome of TQC would be represented as the temporal patterns of biochemical concentrations and rates and there would be hierarchy of p-adic time scales and those associated with the dark matter hierarchy.

For instance, the protein content of lipid membranes is about 50 per cent and varies between 25-75 per cent so that protein folding and lipid flow could define TQC programs as self-organization patterns. The folding of protein is dynamical process: alpha helices are created and disappear in time scale of 10^{-7} seconds and the side chains of protein can rotate.

The details of the TQC like process depend on what one assumes. The minimal scenario is deduced from the transcription and translation processes and from the condition that magnetic body keeps control or at least keeps book about what happens using genome as a tool. The picture would be essentially what one might obtain by applying a rough model for web in terms of nodes and links. The reader is encouraged to use paper and pencil to make the following description more illustrative.

1. Assume that mRNA and DNA remain connected by flux tubes after transcription and that only reconnection process can cut this connection so that mRNA inherits the conjugate colors of DNA. Assume same for mRNA and tRNA. Assume that amino-acid associated with tRNA has similar flux tube connections with the nucleotides of tRNA. Under these assumptions amino-acid inherits the conjugate colors of DNA nucleotides via the connection line DNA-mRNA-tRNA-amino-acid faith-fully if all links are correspond to quark pairs rather than their superpositions. Wobble pairing for Z nucleotide could actually correspond to this kind of superposition.

2. One can consider several options for the amino-acid-acid DNA correspondence but trial-and-error work showed that a realistic folding code is obtained only if X, Y, and Z correspond to $O-H$, $O=$, and NH_2 in the constant part of free amino-acid. During translation the formation of the peptide bond between amino-acids dehydration leads to a loss of $O-H$ and one H from NH_2. The flux tube from tRNA to $O-H$ becomes a flux tube to water molecule inheriting the color of X so that $O=-NH_2$ of the amino-acid inside protein represents the conjugate of YZ.

3. Hydrogen bonding between $O=$ and NH of n: th and $n+k$: th amino-acids inside alpha helices and n: th and $n+1$: th amino-acids inside beta strands reduces effectively to base pairing characterized by $Y=Z$ rule. Assuming that flux tube is only a prerequisite for the formation of hydrogen bond, $Y(n)=Z(n+k)$ or $Z(n)=Y(n+k)$ allows the existence of hydrogen bond. The identification of hydrogen bond with flux tube gives a more stringent condition $Y(n)=Z(n+k)$. The first option is favored. Either condition is extremely restrictive condition on the gene coding the amino-acid unless one assumes quantum counterpart of wobble base pairing for mRNA or tRNA-amino-acid pairing in the case of Z nucleotide (as one indeed must do). Note that the $O=$ atom of the amino-acid is in a special role in that it can have hydrogen bond flux tubes to donors and flux tube connections with $O=$: s of other amino-acids, the residues of amino-acids containing acceptors (say $O=$ or aromatic ring), and with the aromatic rings of say ATP.

4. The recombination process for two conjugate DNA-mRNA-tRNA-amino-acid links can transform the flux tubes in such manner that one obtains link between the $=O$: s of amino-acids A_1 and A_2 characterized by Y and Y_c. Besides hydrogen bonding this mechanism could be central in the enzyme substrate interaction. The process would pair tRNAs corresponding to Y and Y_c together to give DNA-mRNA-tRNA-tRNA-mRNA-DNA link providing a memory representation about amino-acid pairing A_1-A_2. One could say that magnetic body

creates with the mediation of the genome dynamical TQC programs to which much of the bio-molecular activity reduces. Not all however, since two amino-acid pairs $A_1 - A_2$ and $A_3 - A_4$ can recombine to $A_1 - A_4$ and $A_3 - A_2$ without DNA knowing anything about it. Magnetic body would however know.

5. The constant part of non-hydrogen bonded amino-acid inside protein would behave like $Y_c Z_c$ if amino-acid is coded by XYZ. The $COOH$ end of protein would behave like $X_c Y_c Z_c$. Also flux tubes connecting the residue groups become possible and protein does not behave like single nucleotide anymore. By color inheritance everything resulting in the reconnection process between $O =$ and NH_2 and residues reduces in a well-defined sense to the genetic code.

4.7.3 Realization Of Flux Tubes

The basic questions about flux are following. Where do they begin, where do they end, and do they have intermediate plugs which allow temporary cutting of the flux tube.

Where do flux tubes begin from?

The view about magnetic body as a controller of biological body using genome as a control tool suggests that DNA is to a high degree responsible for directed attention and other molecules as targets so that flux tubes emanate from DNA nucleotides. The reason would be that the aromatic cycles of DNA correspond to larger value of Planck constant. Some chemical or geometric property of DNA nucleotides or of DNA nucleotides of DNA strand could raise them to the role of subject. Aromatic cycle property correlates with the symmetries associated with large value of Planck constant and is the best candidate for this property.

If this picture is accepted then also some amino-acid residues might act as subjects/objects depending on the option. Phe, His, Trp, Tyr contain aromatic cycle. The derivatives of Trp and Tyr act as neurotransmitters and His is extremely effective nucleophilic catalyst. This would make possible more specific catalytic mechanisms through the pairing of Phe, His, Trp, and Tyr with residues having flux tube terminals.

This raises the question about the physical interaction determining the color of the strand emerging from the aromatic cycle. The interaction energy of quark at the end of flux tube with the classical electromagnetic fields of nuclei and electrons of the ring should determine this. The wormhole contact containing quark/antiquark at the throat at space-time sheet containing nuclei and electrons could also de-localize inside the ring. One of the earliest hypothesis of TGD inspired model for living matter was that wormhole Bose-Einstein condensates could be crucial for understanding of the behavior of biomolecules [K112]. Wormhole throats with quark and antiquark at their throats appear also in the model of high T_c superconductivity [K19]. As far as couplings are considered, these wormhole contacts are in many respects analogous to the so called axions predicted by some theories of elementary particle physics. The wormhole contact like property is by no means exceptional: all gauge bosons correspond to wormhole contacts in TGD Universe.

The only manner for the electronic space-time sheet to feed its electromagnetic gauge flux to larger space-time sheets using exactly two wormhole contacts is to use wormhole contacts with $\overline{u}$ and d at their "upper" throat (T, G). For proton one would have $\overline{d}$ and u at their "upper" throat (A, C). The presence of electron or proton at nucleotide space-time sheet near the end of flux tube might allow to understand the correlation. The transfer of electrons and protons between space-time sheets with different p-adic length scale is basic element of TGD based model of metabolism so that there might be some relation.

Acceptors as plugs and donors as terminals of flux tubes?

Standardization constraint suggests that flux tubes are attached to standard plugs and terminals. The explicit study of various biological molecules and the role of water in biology gives some hints.

1. An attractive idea is that $= O$ serves as a plug to which flux arrives and from which it can also continue. For the minimal option suggested by hydrogen bonding $O =$ could be connected to two donors and $O =$ could not be connected to $O =$. The assumption that the

flux tube can connect also two $O =:$ s represents a hypothesis going outside the framework of standard physics. A stronger assumption is that all acceptors can act as plugs. For instance, the aromatic rings of DNA nucleotides could act as acceptors and be connected to a sequence of $O =$ plugs eventually terminating to a hydrogen bond.

2. Donors such as $O - H$ would in turn correspond to a terminal at which flux tube can end. One might be very naïve and say that conscious bio-molecules have learned the fundamental role of oxygen and water in the metabolism and become very attentive to the presence of $= O$ and $O - H$. $= O$ appears in $COOH$ part of each amino-acid so that this part defines the standard plug. $= O$ appears also in the residues of Asp, Glu, Asn, Gln. $O - H$ groups appear inside the residues of Asp, Glu and Ser, Thr.

3. Hydrogen bonds $X - H - -Y$ have the basic defining property associated with directed attention, namely the asymmetry between donor X and acceptor Y. Hence there is a great temptation consider the possibility that hydrogen bonds correspond to short flux tubes, that flux tubes could be seen as generalized hydrogen bonds. Quite generally, Y could be seen as the object of directed attention of X characterized by larger value of Planck constant. The assumption that two $O =:$ s, or even two acceptors of a hydrogen bond, can be connected by a flux tube means more than a generalization of hydrogen bond the connection with a donor would correspond only to the final step in the sequence of flux tubes and plugs giving rise to a directed attention.

4. This hypothesis makes the model rather predictive. For instance, $N - H$, NH_2, $O - H$ and much less often $C - H$ and $S - H$ are the basic donors in the case of proteins whereas $O =$, $-O-$, $-N = S - S$, $-S^-$ and aromatic rings are the basic acceptors. Reconnection process should be involved with the dynamics of ordinary hydrogen bonding. Reconnection process implies inheritance of the flux tube color and means a realization of the symbol based dynamics. It turns out that this hypothesis leads to a model explaining basic qualitative facts about protein folding.

4.7.4 Flux Tubes And DNA

The model of DNA as topological quantum computer gives useful guide lines in the attempt to form a vision about flux tubes. It was assumed that braid strands defined by "wormhole magnetic" flux tubes join nucleotides to lipids and can continue through the nuclear or cell membrane but are split during TQC. The hydrophilic ends of lipids attach to water molecules and self-organization patterns for the water flow in gel phase induce a 2-D flow in the lipid layer which is liquid crystal defining TQC programs at the classical level as braidings. The flow indeed induces braiding if one assumes that during topological computation the connection through the cell membrane is split and reconnected after the halting of TQC.

The challenge is to understand microscopically how the flux tube joins DNA nucleotide to the phospholipid [I47]. Certainly the points at which the flux tubes attach should be completely standard plugs and the formation of polypeptide bonds is an excellent guide line here. Recall that phospholipid, the TQC dancer, has two hydrophobic legs and head. Each leg has at the hydrophilic end O=C-O-C part joining it to glyceride connected to monophosphate group in turn connected to a hydrophilic residue R. The most often appearing residues are serine, inositol, ethanolamine, and choline. Only three of these appear in large quantities and there is asymmetry between cell exterior and interior.

Let us denote by $= O_1$ and $= O_2$ the two oxygens (maybe analogs of right and left hemispheres!) in question. The proposal is that DNA nucleotide and $= O_1$ are connected by a flux tube: the asymmetry between right and left lipid legs should determine which of the legs is "left leg" and which $O =$ is the "left brain hemisphere". $= O_2$, the "holistic right brain hemisphere", connects in turn to the flux tube coming from the other symmetrically situated $= O_2$ at the outer surface of the second lipid layer. Besides this $= O_1$ and $= O_2$ are connected by a flux tube serving as switch on both sides of the membrane.

During TQC the short $O = -O =$ flux tube would experience reconnection with a flux tube acting as hydrogen bond between water molecules so that the connection is split and $O =:$ s form hydrogen bonds. The reversal of this reconnection creates the connection again and halts the

computation. The lipid residue R couples with the flow of the liquid in gel phase. Since $=O$ is in question the quark or antiquark at the end can correspond to the DNA nucleotide in question. The necessary complete correlation between quark and antiquark charges at the ends of flux tubes associated with $=O_1$ and $=O_2$ can be understood as being due to the minimization of Coulomb interaction energy.

If one is ready to accept magnetic flux tubes between all acceptors then the aromatic rings of nucleotides known to be acceptors could be connected by a flux tube to the $O=$ atom of the lipid or to some intermediate $O=$ atom. The phosphate groups associated with nucleotides of DNA strand contain also $=O$, which could act as a plug to which the flux tube from the nucleotide is attached. The detailed charge structure of the aromatic ring(s) should determine the quark-nucleotide correspondence. The connection line to the lipid could involve several intermediate $O=$ plugs and the first plug in the series would be the $O=$ atom of the monophosphate of the nucleotide.

There is a strong temptation to assume that subset of XYP molecules, $X = A, G, T, C$, $Y = M, D, T$ act as standard plugs with X and phosphates connected by flux tubes to a string. This would make possible to engineer braid strands from standard pieces connected by standard plugs. DNA nucleotide XMP would have flux tube connection to the aromatic ring of X and the $O=$ of last P would be connected to next plug of the communication line. If so, a close connection with metabolism and topological quantum computation would emerge. Phosphorylation would be an absolutely essential for both metabolism and buildup of connection lines acting as braid strands. $O = -O =$ flux tubes could also act as switches inducing a shortcut of the flux tube connection by reconnecting with a hydrogen bond connecting two water molecules. This is an essential step in the model for how DNA acts as topological quantum computer.

This picture would fit with the fact that XYP molecules, in particular AMP, ADP, and ATP, appear in bio-molecules involved with varying functions such as signalling, control, and metabolism. $=O$ might act as a universal plug to which flux tubes from electronegative atoms of information molecules can attach their flux tubes. This would also provide a concrete realization of the idea that information molecules (neurotransmitters, hormones) are analogous to links in Internet [K80]: they would not represent the information but establish a communication channel. The magnetic flux tube associated with the information molecule would connect it to another cell and by the join to $=O$ plug having flux tube to another cell, say to its nucleus, would create a communication or control channel.

4.7.5 Introns And DNA-Protein Attachment

An example is the situation in which protein acts as an enzyme attaching on DNA. Suppose that this process effectively reduces to a base pairing between amino-acid and DNA nucleotide. Protein can attach to any portion of DNA. The simplest interaction is the attachment to the gene coding for the amino-acid itself but much more general enzymatic interactions are possible. It must be however noticed that DNA sequence coding for given amino-acid sequences is considerably longer than amino-acid sequence: the sequence coding for 10 amino-acids is about 10 nm long whereas the corresponding straight amino-acid strand is about 4.7 nm long. It is known that DNA can change its conformation from strand during enzyme-DNA action [I133], and the contraction of DNA strand might make possible to have enzyme-DNA interaction involving fusion along several subsequent amino-acids. This kind of mechanism might work also in the case that attachment region corresponds to several exons. There is however no need to assume that subsequent amino-acids are form a contact with DNA.

One can of course ask whether genes containing introns tend to code for proteins which are used for topological quantum computations. Introns, perhaps the repeating sequences with no obvious function, would have at least this useful function but very probably much more useful ones too (they are now known to be transcribed to RNA and TGD suggest that language corresponds to intronic gene expression). The emergence of introns might be somewhat like the emergence of information society.

The folding of proteins tends to be conserved in the evolution whereas primary structure can change quite a lot apart from some amino-acids critical for enzymatic action. This confirms with the effective base pairing interaction between amino-acids and DNA to be discussed later and would mean that DNA-amino-acid TQC programs are rather robust against mutations.

Flux tubes and DNA

The model of DNA as topological quantum computer gives useful guide lines in the attempt to form a vision about flux tubes. It was assumed that braid strands defined by "wormhole magnetic" flux tubes join nucleotides to lipids and can continue through the nuclear or cell membrane but are split during TQC. The hydrophilic ends of lipids attach to water molecules and self-organization patterns for the water flow in gel phase induce a 2-D flow in the lipid layer which is liquid crystal defining TQC programs at the classical level as braidings. The flow indeed induces braiding if one assumes that during topological computation the connection through the cell membrane is split and reconnected after the halting of TQC.

The challenge is to understand microscopically how the flux tube joins DNA nucleotide to the phospholipid [I46]. Certainly the points at which the flux tubes attach should be completely standard plugs and the formation of polypeptide bonds is an excellent guide line here. Recall that phospholipid, the TQC dancer, has two hydrophobic legs and head. Each leg has at the hydrophilic end O=C-O-C part joining it to glyceride connected to monophosphate group in turn connected to a hydrophilic residue R. The most often appearing residues are serine, inositol, ethanolamine, and choline. Only three of these appear in large quantities and there is asymmetry between cell exterior and interior.

1. Are the flux tubes beginning from O=: s special?

Let us denote by $= O_1$ and $= O_2$ the two oxygens (maybe analogs of right and left hemispheres!) in question.

1. The proposal is that DNA nucleotide and $= O_1$ are connected by a flux tube: the asymmetry between right and left lipid legs should determine which of the legs is "left leg" and which $O =$ is the "left brain hemisphere". $= O_2$, the "holistic right brain hemisphere", connects in turn to the flux tube coming from the other symmetrically situated $= O_2$ at the outer surface of the second lipid layer. Besides this $= O_1$ and $= O_2$ are connected by a flux tube serving as switch on both sides of the membrane.

2. During TQC the short $O = -O =$ flux tube would experience reconnection with a flux tube acting as hydrogen bond between water molecules so that the connection is split and $O =$: s form hydrogen bonds. The reversal of this reconnection creates the connection again and halts the computation. The lipid residue R couples with the flow of the liquid in gel phase. Since $= O$ is in question the quark or antiquark or a pair of electron pairs at the end can correspond to the DNA nucleotide in question. The necessary complete correlation between quark and antiquark charges at the ends of flux tubes associated with $= O_1$ and $= O_2$ might be understood as being due to the minimization of Coulomb interaction energy. In the case of pair of electron pairs the correlation could come from the minimization of the magnetic energy.

3. If one is ready to accept magnetic flux tubes between all acceptors then the aromatic rings of nucleotides known to be acceptors could be connected by a flux tube to the $O =$ atom of the lipid or to some intermediate $O =$ atom. The phosphate groups associated with nucleotides of DNA strand contain also $= O$, which could act as a plug to which the flux tube from the nucleotide is attached. The detailed charge structure of the aromatic ring(s) should determine the quark-nucleotide correspondence. The connection line to the lipid could involve several intermediate $O =$ plugs and the first plug in the series would be the $O =$ atom of the monophosphate of the nucleotide.

There is a strong temptation to assume that subset of XYP molecules, $X = A, G, T, C$, $Y = M, D, T$ act as standard plugs with X and phosphates connected by flux tubes to a string. This would make it possible to engineer braid strands from standard pieces connected by standard plugs. DNA nucleotide XMP would have flux tube connection to the aromatic ring of X and the $O =$ of last P would be connected to next plug of the communication line. If so, a close connection with metabolism and topological quantum computation would emerge.

1. Phosphorylation [I48] would be an absolutely essential for both metabolism and buildup of connection lines acting as braid strands. Phosphorylation is indeed known to be the basic

step activating enzymes. In eukaryotes the phosphorylation takes plane amino-acids most often for ser but also thr, and trp with aromatic rings are phosphorylated. Mitochondrions have specialized to produce ATP in oxidative phosphorylation from ADP and photosynthesis produces ATP. All these activities could be seen as a production of standard plugs for braid strands making possible directed attention and quantum information processing at molecular level.

2. As already noticed, $O = -O =$ flux tubes could also act as switches inducing a shortcut of the flux tube connection by reconnecting with a hydrogen bond connecting two water molecules. This is an essential step in the model for how DNA acts as topological quantum computer. De-phosphorylation might be standard manner to realize this process.

3. This picture would fit with the fact that XYP molecules, in particular AMP, ADP, and ATP, appear in bio-molecules involved with varying functions such as signalling, control, and metabolism. $= O$ might act as a universal plug to which flux tubes from electronegative atoms of information molecules can attach their flux tubes. This would also provide a concrete realization of the idea that information molecules (neurotransmitters, hormones) are analogous to links in Internet [K80]: they would not represent the information but establish a communication channel. The magnetic flux tube associated with the information molecule would connect it to another cell and by the join to $= O$ plug having flux tube to another cell, say to its nucleus, would create a communication or control channel.

2. DNA as topological quantum computer hypothesis and electronic super-conductivity

The vision about DNA as topological quantum computer is very general. The essential element is the coding of DNA nucleotides and one can imagine several options.

1. One realization is based on the representation of DNA nucleotides A, T, C, G as quarks u, d and their antiquarks and requires scaled up version of QCD. The motivation for this realization came from the observation of Barbara Shipman that the mathematical description of honeybee dance suggests that quarks play a role in living matter [A6].

2. Second option that one can imagine would use spin 1 triplet and spin 0 singlet of dark electron pair. Spin 0 state for electron pair however gives rise to vanishing dipole field so that flux tube structure would not be possible. Can one circumvent this option or are quark pairs unavoidable?

3. DNA as TQC lead to the hypothesis that it is O= to which one must assign the flux tube pair responsible for the representation of the genetic code. Why O= would be in special role?

   (a) If there are two parallel flux tubes, one obtains tensor product $3 \times 3 = 5+3+1$ of electron triplets at the ends of the flux tubes. Could it be that A, T, C, and G are represented in terms of 3 and 1 and the breaking of rotational invariance implies a mixing of singlet and spin 0 state of triplet so that nucleotides and their conjugates could correspond to the resulting two pairs related by reflection?

   One can however argue that for $S_z = 0$ states the direction of the magnetic flux tubes is orthogonal to that in other cases. An alternative possibility is that one uses only the four $S_z \neq 0$ states of spin 2 5-multiplet obtained in the tensor product. The breaking of the full rotational symmetry down to SO(2) symmetry around flux tube direction could be used to justify this option.

   (b) The coding would be also consistent with quantum classical correspondence since it would reduce at classical level to a coding in terms of directions of magnetic fields in the two flux tubes: the directions could be parallel and in two directions or antiparallel giving also two options: four altogether. Notice however that one must be able to distinguish between two different configurations in which the directions of magnetic flux are opposite for the flux tubes of the pair. Classically this is achieved if the flux tubes form either a right-handed or left-handed double helix. Double helix could also resolve the problem posed by the fact that in $S_z = 0$ case the flux tubes cannot be parallel to their common axis at the flux tube end.

(c) This option would allow a unification of DNA as topological quantum computer conjecture with the conjectures about dark high T_c super-conductivity and negentropic entanglement.

$ATP \to ADP + P_i$ would correspond to the fusion of flux tube pair with two hydrogen bonds associated with water molecules so what they could become short-circuited with water molecules. The reverse process would create flux tube connection labelled by the spin state equivalent of A, T, C, or G. The possibility of 5-plet allows also to consider the possibility of five codons instead of four.

Whatever the correct option is it must explain how the correspondence between A, T, C, G and secondary codons emerges.

1. If the pairs of spin triplet electron pairs appear in the correspondence, one must understand why the spin state of the pair of electron pairs at the O= of the phosphate attached with the DNA nucleotide correlates with the character of the nucleotide. Phosphate has also two O^-: s containing two electron pairs. Minimization of the magnetic energy is the explanation which is easiest to imagine. Maybe the total magnetic energy of the pair in the magnetic field of the flux tube structure assignable to the nucleotide plus the de-oxyribose preceding it. T and C contain also O= but not A and G. and A and T and C and G are conjugates.

   By studying the chemical structure of DNA (see `http://tinyurl.com/yd7b7w98`) [I90] one finds that the pairs AT and CG contain two O=: s which belong either to same nucleotide (to T in A-T) or to different nucleotides (C-G). This suggests the coding in which there are flux tube pairs connecting the two phosphate O=s at the two sides of the double strand and going through the two intermediation O=s. The rule would be that the spin states are conjugates at the ends of the flux tubes. A-T and T-A pairs could correspond to parallel flux tubes with same direction of the flux and G-C and C-G to parallel flux tubes with opposite directions of the magnetic fluxes.

2. If quark pairs are unavoidable, the correspondence of A, T, C, G with quarks and antiquark must relate to quark charges coming as $\pm 2/3$, $\pm 1/3$. Also in this case the coding mechanism based on the flux tubes connecting O=: s is natural.

The conclusion would be that the original view about secondary realization of genetic code can be replaced with the realization based on spin 1 dark Cooper pairs of electrons between which the entanglement is negentropic. Quark color plays no special role in the model of DNA as topological quantum computer [K3] so that the model remains as such. One implication would be however that the magnetic flux tubes carrying dark electron pairs at their ends could be of astrophysical size.

4.7.6 Some Predictions Related To The Representation Of Braid Color

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

Anomalous em charge of DNA as a basic prediction

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

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

$$Q_a = [n(A) - n(T)]Q(q_A) + [n(G) - n(C)]Q(q_G) \tag{4.7.1}$$

is predicted. The four possible options for charge are given explicitly in **Table 4.2**.

$$\begin{array}{l} Q_a = [n(A)-n(T)]\frac{2}{3} - [n(G)-n(C)]\frac{1}{3} \ , \\ Q_a = -[n(A)-n(T)]\frac{1}{3} + [n(G)-n(C)]\frac{2}{3} \ , \\ Q_a = -[n(A)-n(T)]\frac{2}{3} + [n(G)-n(C)]\frac{1}{3} \ , \\ Q_a = [n(A)-n(T)]\frac{1}{3} - [n(G)-n(C)]\frac{2}{3} \ . \end{array} \tag{4.7.2}$$

Table 4.2: Table show four possible options for em charge as sum of quark charges.

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

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

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

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

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

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

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

Chargaff's second parity rule states that the frequencies of nucleotides for single DNA strand satisfy the conditions $p(A) \simeq p(T)$ and $p(C) \simeq p(G)$ (I am grateful for Faramarz Faghihi for mentioning this rule and the related [H3] [I139] to me). This rule holds true in a good approximation. In the recent context the interpretation would be as the vanishing of the net anomalous charge of the DNA strand and thus charge conjugation invariance. Stability of DNA might explain the rule and the poly-A tail in the untranslated mRNA could relate stabilization of DNA and mRNA strands.

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

$$\begin{array}{ll} p(A)+p(C) \simeq 1/2 \ , & p(A)+p(G) \simeq 1/2 \ , \\ p(T)+p(C) \simeq 1/2 \ , & p(T)+p(G) \simeq 1/2 \ . \end{array} \tag{4.7.3}$$

An interesting empirical finding [I139] is that only some points at the line $p(A)+p(C) \simeq 1/2$ are realized in the case of human genome and that these points are in a good accuracy expressible in terms of Fibonacci numbers resulting as a prediction of optimization problem in which Fibonacci numbers are however put in by hand. $p(A)=p(G)=p(C)=p(T)=1/4$ results as a limiting case. The poly-A tail of mRNA (not coded by DNA) could reflect to the compensation of this asymmetry for translated mRNA.

The physical interpretation would be as a breaking of isospin symmetry in the sense that isospin up and down states for quarks (A and G *resp.* T and C) do not appear with identical probabilities. This need not have any effect on protein distributions if the asymmetry corresponds

to asymmetry for the third nucleotide of the codon having $A \leftrightarrow G$ and $T \leftrightarrow C$ symmetries as almost exact symmetries. This of course if protein distribution is invariant under this symmetry for the first two codons.

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

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

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

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

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

1. The division of the gene into structural sub-units correlates with the separation into color singlets. Thus various structural sub-units of gene (say transcribed part, translated part, intronic portions, etc...) would be color singlets.

2. Also different genetic codes that I have discussed in [**?**] could distinguish between different structural sub-units. For this option only gene - understood as TQC unit with un-transcribed regions included - would be color singlet.

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

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

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

$$n(A) + n(G) \ \ mod \ \ 3 = 0 \ , \quad n(C) + n(T) \ \ mod \ \ 3 = 0 \ . \tag{4.7.4}$$

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

2. General condition for integer valued anomalous charge

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

$$n(A) - n(T) + n(G) - n(C) \ \ mod \ \ 3 = 0 \ . \tag{4.7.5}$$

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

A possible interpretation is in terms of TGD based model for pre-biotic evolution [**?**] according to which genetic code (or 3-code) was formed as a fusion of 2-code and 1-code. 2-code and 1-code could still be present in genome and be associated with non-translated regions of mRNA

preceding and following the translated region. The genes of 2-code and coding for RNA would have $2n$ nucleotides and the genes of 1-code could also consist of odd number of nucleotides.

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

1. Repeating sequences consisting of n copies of same repeating unit could obey 1-code or 2-code. The simplest building blocks of repeating sequences are AT and CG having vanishing anomalous em charge. TATATA.... and CGCGCG... indeed appear often. Also combinations of CG and AT could repeat: so called mini-satellites are CG rich repeating sequences. Interpretation in terms of 2-code suggests itself.

2. Triplet of the unit ATTCG with integer charge repeats also often: in this case 3-code suggests itself. Telomeres of vertebrates consist of a repeating unit TTAGGG which does not have integer charge: this unit appears also as 8-nucleotide variant which suggests 2-code. Color singletness would require that this unit appears $3n$ times.

3. I have also proposed that intronic regions could obey memetic code [K43] predicting that intronic codon can be represented as a sequence of 21 3-codons (implying 2^{63} 63-codons!). Individual intronic segments need not satisfy this rule, only their union if even that. Direct experimentation with gene bank data show that neither introns nor their union correspond to integer multiples of 63 nor 3 or 2 in general.

3. Color singletness conditions for gene

Gene is usually defined as the sequence of DNA coding for mRNA. mRNA involves also two untranslated regions (UTRs) [I2].

1. The $5'$ end of mRNA contains $5'$ cap (methylated G) and $5'$ untranslated region (UTR). The latter can be several kb long for eukaryotes. Methylated G is not coded by DNA but added so that it does not contribute to A+G-T-C count at DNA level.

2. mRNA continues after the stop codon as $3'$ UTR. Translation assigns to UTR also a poly-A tail (up to several hundreds A: s) not coded by DNA and not contributing to A+G-T-C count in the case of DNA. This region contains also AAUAAA which does not contribute to A+G-T-C count of mRNA.

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

4. Color singletness conditions for mRNA

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

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

$$n(A) - n(T) + n(G) - n(C) + n_{tail}(A) + 1 \ \ mod \ \ 3 = 0 \tag{4.7.6}$$

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

5.Chargaff's rule for mRNA

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

$$\begin{aligned} &2\,[n(A)+n_{tail}(A)-n(T)]-[n(G)+1-n(C)]\simeq 0\ ,\\ &-[n(A)+n_{tail}(A)-n(T)]+2\,[n(G)+1-n(C)]\simeq 0\ ,\\ &-2\,[n(A)+n_{tail}(A)-n(T)]+[n(G)+1-n(C)]\simeq 0\ ,\\ &[n(A)+n_{tail}(A)-n(T)]-2\,[n(G)+1-n(C)]\simeq 0\ . \end{aligned} \tag{4.7.7}$$

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

6. Moving genes and repeating elements

Transposons [I64], [J16] are moving or self-copying genes. Moving genes cut from initial position and past to another position of double strand. Copying genes copy themselves first to RNA and them to a full DNA sequence which is then glued to the double strand by cut and paste procedure. They were earlier regarded as mere parasites but now it is known that their transcription is activated under stress situations so that they help DNA to evolve. In TQC picture their function would be to modify TQC hardware. For copying transposons the cutting of DNA strand occurs usually at different points for DNA and cDNA so that "sticky ends" result ("overhang" and its complement) [I59]. Often the overhang has four nucleotides. The copied transposon have ends which are reversed conjugates of each other so that transposons are palindromes as are also DNA hairpins. This is suggestive of the origin of transposons.

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

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

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

3) The overhangs should satisfy P.

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

In the example mentioned in [I57] the overhang is $CTAG$ and has vanishing Q_a. The cut site $CCTAGG$ has also vanishing Q_a. It is known [J16] that transposons - repeating regions themselves - tend to attach to the repeating regions of DNA [I16].

1. There are several kinds of repeating regions. 6-10 base pair long sequences can be repeated in untranslated regions up to 10^5 times and whole genes can repeat themselves $50-10^4$ times.

2. Repeats are classified into tandems (say TTAGGG associated with telomeres), interspersed repetitive DNA (nuclear elements), and transposable repeat elements. Interspersed nuclear elements (INEs) are classified LINEs (long), SINEs (short), TLTRs (Transposable elements with Long Terminal Repeats), and DNA transposons themselves.

3. LINEs contain AT rich regions. SINEs known as alus (about 280 bps) contain GC rich regions whereas mariner elements (about 80 bps) are flanked by TA pairs. LTRs have length 300-1000 bps. DNA transposons are flanked with two short inverted repeat sequences flanking the reading frame: "inverted" refers to the palindrome property already mentioned.

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

7. Tests

Some checks of the color singletness hypothesis were made for human genome [I25].

1. For the coding sequences (CDSs) the strong prediction in general fails as expected (condition would pose restrictions on possible amino-acid contents).

2. Color singletness condition fails for genes defined in terms of translated part of mRNA (with gap and poly-A tail excluded). The un-transcribed regions of DNA involved with the gene expression (promoter region, etc...) could guarantee the color singletness. They could also stabilize DNA by bringing in compensating anomalous charge to guarantee second Chargaff's rule. Different genetic codes could distinguish between the subunits of gene.

3. To test color singletness conditions for mRNA one should know the length of poly-A tail. Unfortunately, I do not have access to this information.

4. The computation of total anomalous charges for a handful of genes, introns, and repeat units for some gene bank examples in the case of human genome indicates that both of them tend to carry net em charge which is largest for $(a, g) \leftrightarrow (\overline{d}, \overline{u})$ correspondence. The charge is in the range 5-10 per cent from the charge associated with the phosphates (-2 units per nucleotide). For second option giving negative charge (permute u and d) the anomalous charge is few per cent smaller.

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

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

6. The predictions for transposons and their cut and past process should be easily testable.

Summary of possible symmetries of DNA

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

1. Color confinement in strong form

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

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

2. Matter antimatter asymmetry at quark level

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

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

3. Isospin symmetry at quark level

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

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

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

1. For almost all type A codons the amino-acid coded by the codon does not depend on the last nucleotide. There are two exceptions in the case of the nuclear code: (leu, leu, phe, phe) and (ile, ile, ile, met). For human mitochondrial code one has (ile, ile, ile, ile) and thus only one exception to the rule. The breaking of matter-antimatter symmetry for the third nucleotide is thus very small.

2. For codons of type B the 4-columns code always for two doublets in the case of vertebrate mitochondrial code so that for codons with vanishing net quark number the breaking of matter-antimatter symmetry for the third nucleotide is always present.

5. Em stability

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

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

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

6. Summary of testable working hypothesis

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

1. Gene plus control region and also DNA repeats should have property P. Transcribed and control regions of gene have Q_a with opposite signs.

2. Transposons, repeating regions, the overhangs associated with the cut and paste of transposon, and the DNA strands resulting in cutting should have property P. This could explain why transposons can paste themselves to AT and GC ($Q_a = 0$) rich repeating regions of

DNA. The points at which DNA can be cut should differ by a DNA section having property P. This gives precise predictions for the points at which transposons and pieces of viral DNA can join and could have implications for genetic engineering.

3. If also mRNA is braided, it has property P. This can be only true if the poly-A tail compensates for the non-vanishing Q_a associated with the translated region.

4. Living hairpins should have property P. If only double helix parts of hairpins are braided, the prediction is trivially true by the palindrome property. tRNA or at least parts of it could be braided. Braids could end to the nuclear membrane or mRNA or to the amino-acid attachable to tRNA. For stem regions Q_a is integer valued. The fact that the nucleotide of the anticodon corresponding to the third nucleotide of codon can base pair with several nucleotides of mRNA suggests that $I(nositol)$ can have Q_a opposite to that of A, T, C and U opposite to that of A, G. For 2-anticodon the pairing would be unique. This would give a lot of freedom to achieve property P in weak sense for tRNA. Braid structure for tRNA + amino-acid could be different that for tRNA alone and also in the translation the braid structure could change.

5. Telomeres [I61] are of special interests as far as anomalous em charge is considered. Chromosomes are not copied completely in cell replication, and one function of telomeres is to guarantee that the translated part of genome replicates completely for sufficiently many cell divisions. Telomeres consists of 3-20 kilobases long repetitions of TTAGGG, and there is a 100-300 kilobases long repeating sequence between telomere and the rest of the chromosome. Telomeres can form can also 4-stranded structures. Telomere end contains a hair-pin loop as a single stranded part, which prevents the action of DNA repair enzymes on the chromosome end. Telomerase is a reverse transcriptase enzyme involved with the synthesis of telomeres using RNA strand as a template but since its expression is repressed in many types of human cells, telomere length shortens in each cell replication. In the case of germ cells, stem cells and white blood cells telomerase is expressed and telomere length preserved. Telomere shortening is known to relate to ageing related diseases. On the other hand, overactive telomere expression seems to correlate with cancer.

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

6. Also amino-acids could be braided. Q_a could vary and correspond to Q_a for one of the codons coding for it. The amino-acid sequences of catalysts attaching to DNA strand should have opposite Q_a for each codon-amino-acid pair so that amino-acid would attach only to the codons coding for it. The TGD based model for nerve pulse [K80] inspires the proposal that magnetic flux tubes connecting microtubules to the axonal membrane allow TQC during nerve pulse propagation when axonal membrane makes transition from gel like phase to liquid crystal phase. Amino-acids of tubulin dimers would be connected by 3-braids, smallest interesting braid, to groups of 3-lipids in axonal membrane and tubulin dimers would define fundamental TQC modules.

Empirical rules about DNA and mRNA supporting the symmetry breaking picture

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

1. The vanishing of the induced Kähler field means that the space-time sheet of DNA is a highly unstable vacuum extremal. The non-vanishing of the induced Kähler electric field is thus a natural correlate for both the stability and the non-vanishing quark number density (matter antimatter asymmetry). The generation of matter antimatter asymmetry induces a net density of anomalous em charge, isospin, and quark number in the portion of DNA considered. This in turn generates not only longitudinal electric field but also a longitudinal Kähler electric field along DNA.

2. Weak electric fields play a key role in living matter. There are electric fields associated with embryos, central nervous system, individual neurons, and microtubules and their direction determines the direction of a process involved (head-to-tail direction, direction of propagation of nerve pulse, ...).

3. Same mechanism is expected to be at work also in the case of DNA and RNA. In the case of gene the direction of transcription could be determined by the direction of the electric field created by gene and telomeres at the ends of chromosomes carrying a net anomalous quark number could be partially responsible for the generation of this field. In the case of mRNA the direction of translation would be determined in the similar manner. The net anomalous em charges of poly-A tail and the transcribed part of mRNA would have opposite signs so that a longitudinal electric field would result.

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

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

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

Table 4.3 gives A, T, C, G contents (these data are from Wikipedia [I8]) provides interesting data about DNA It will be found that so called Szybalski's rules can be interpreted as saying that for coding regions there is breaking of the approximate matter antimatter asymmetry.

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

For option 2) the amount of anomalous charge is about.0057e per nucleotide and thus about $3 \times 10^7 e$ for entire human DNA having length of about 1.8 meters. The inspection of tables of [I61] shows that the anomalous em charge for the repeating sequence defining the telomere is always non-vanishing and has always the same sign. Telomeres for human chromosomes consist of TTAGGG repetitions with anomalous em charge with magnitude $5e/3$ for all options and have a length measured in few kbases. Human genome as has 24 chromosomes so that the total anomalous em charge of telomeres is roughly $24 \times (5/18) \times x10^3 e \sim .8 \times 10^3 xe$, $1 < x < 10$. The anomalous em charge of telomeres is three orders of magnitude smaller than that of entire DNA but if DNA is quantum critical system the change the total anomalous em charge and quark number due to the shortening of telomeres could induce instabilities of DNA (due to the approach to vacuum extremal) contributing to ageing. Note that the small net value of quark number in all the cases considered might be necessary for overall stability of DNA. Telomeres are also known to prevent the ends of chromosomes to stick to each other. This could be partially due to the Coulomb repulsion due to the anomalous em charge.

According to [I8] Chargaff's rules do not apply to viral organellar genomes (mitochondria [I38], plastids) or single stranded viral DNA and RNA genomes. Thus approximate matter antimatter symmetry fails for DNA: s of organelles involved with metabolism. This might relate to the fact that the coding portion of DNA is very high and repeats are absent. Chargaff's rule applies not only to nucleotides but also for oligonucleotides which corresponds to DNA or RNA sequences with not more than 20 bases. This means that for single strand oligonucleotides and their conjugates appear in pairs. Matter antimatter asymmetry would be realized as presence

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

(4.7.8)

Table 4.3: The table gives A, T, C, G contents (these data are from Wikipedia [I8]), the amount of quark charge per nucleotide for the options 1) *resp.* 2) given by $dq_1/dn = p[2(A-T)-G-C)]/3$ *resp.* $dq_2/dn = p[A-T-2(G-C)]/3$, the amount $dI_3/dn = p(A-G+C-T]/2$ of isospin per nucleotide, the amount $d(q-\overline{q})/dn = p(A-T+G-C)$ of quark number per nucleotide, and $(A+T)/(C+G)$ ratio for *entire genomes* in some cases.

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

8. Breaking of matter antimatter symmetry for coding regions

As noticed, one can consider three type of symmetry breaking parameters for DNA in DNA as TQC model. There are indeed three empirical parameters of this kind. Chargaff rules have been already discussed and correspond to approximate matter antimatter symmetry. The second asymmetry parameter would measure the asymmetry between $u\overline{u}$ and $d\overline{d}$ type matter. $p(G+C)$ corresponds to the fraction of $d\overline{d}$ type quark matter for option 1) and $u\overline{u}$ matter for option 2). It is known that G+C fraction $p(G+C)$ characterizes genes [I116] and the value of $p(G+C)$ is proportional to the length of the coding sequence [I30, I116].

Besides Chargaff rules holding true for entire genome also Szybalski's rules [I8] hold true but only for coding coding regions. The biological basis of neither rules is not understood. The interpretation of Chargaff's rules would be in terms of approximate matter antimatter symmetry and the vanishing of net isospin at the level of quarks whereas Szybalski's rule would state the breaking of these symmetries non-coding regions. Hence all the three basic empirical rules would have a nice interpretation in DNA as TQC picture.

Consider now Szybalski's rules in more detail.

1. In most bacterial genomes (which are generally 80-90 % coding) genes are arranged in such a fashion that approximately 50 % of the coding sequence lies on either strand. Note that either strand can act as a template (this came as a surprise for me). Szybalski, in the 1960s, showed that in bacteriophage coding sequences purines (A and G) exceed pyrimidines (C and T). This rule has since been confirmed in other organisms and known as Szybalski's rule [I8, I117]. While Szybalski's rule generally holds, exceptions are known to exist.

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

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

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

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

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

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

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

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

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

1. In nuclear physics the neutron to proton ratio of nucleus increases as nucleus becomes heavier so that the nuclear isospin becomes negative: $I_3 < 0$. The increase of the nuclear mass corresponds to the increase for the length of the coding region. Since G/A fraction increases with the length of coding region, G should correspond to either d quark ($(Q_a < 0, I_3 = -1/2)$) or its charge conjugate d_c ($Q_a < 0$). Hence option 1) or its charge conjugate would be favored.

2. If one takes very seriously the analogy with cosmic matter antimatter asymmetry then matter should dominate and only $(A, G, T, C) \to (u, d, \overline{u}, \overline{d})$ option would remain.

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

Genetic codes and TQC

TGD suggests the existence of several genetic codes besides 3-codon code [K44, **?**]. The experience from ordinary computers and the fact that genes in general do not correspond to $3n$ nucleotides encourages to take this idea more seriously. The use of different codes would allow to tell what kind of information a given piece of DNA strand represents. DNA strand would be like a drawing

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

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

The hierarchy of Mersenne primes $M_n = 2^n - 1$ with $M_{n(next)} = M_{M_n}$ starting from $n = 2$ with $M_2 = 3$ gives rise to 1-code with 4 codons, 3-code with 64 codons, and $3 \times 21 = 63$-code with 2^{126} codons [K44] realized as sequences of 63 nucleotides (the length of 63-codon is about $2L(151)$, roughly twice the cell membrane thickness. It is not known whether this Combinatorial Hierarchy continues ad infinitum. Hilbert conjectured that this is the case.

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

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

There are also further short Combinatorial hierarchies corresponding to Mersenne primes [A2].

1. $n = 13$ defines Mersenne prime M_{13}. The code would have $2^{12=6\times 2}$ codons representable as sequences of 6 nucleotides or 2 3-codons. This code might be associated with microtubuli.

2. The Fermat prime $17 = 2^4 + 1$ defines Mersenne prime M_{17} and the code would have $2^{16=8\times 2}$ codons representable as sequences of 8 nucleotides.

3. $n = 19$ defines Mersenne prime M_{19} and code would have $2^{18=9\times 2}$ codons representable as sequences of 9 nucleotides or three DNA codons.

4. The next Mersennes are M_{31} belonging to $n = 5$ hierarchy, M_{61} with $2^{60=30\times 2}$ codons represented by 30-codons. This corresponds to DNA length $L(151) = 10$ nm (cell membrane thickness). M_{89} (44-codons), M_{107} (53-codons) and M_{127} (belonging to the basic hierarchy) are the next Mersennes. Next Mersenne corresponds to M_{521} (260-codon) and to completely super-astrophysical p-adic length scale and might not be present in the hierarchy.

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

4.8 Cell Replication And TQC

DNA as TQC model leads to quite detailed ideas about the evolution of the genetic code and the mechanisms of bio-catalysis and of protein folding [**?**]. These applications in turn leads to a considerable generalization of DNA as TQC concept [**?**] . The presence of braiding leads also to a revision of the model of nerve pulse and EEG [K80, K35]. Here the discussion is restricted to one particular example. One can look what happens in the cell replication in the hope of developing more concrete ideas about TQC in multicellular system. This process must mean a replication of the braid's strand system and a model for this process gives concrete ideas about how multicellular system performs TQC.

4.8.1 Mitosis And TQC

Mitosis is the form of cell replication yielding soma cells and it is interesting what constraints this process gives on TQC and whether the special features of this process could be understood from computational point of view.

1. During mitosis chromosomes [I39] are replicated. During this process the strands connecting chromosomes become visible: the pattern brings in mind flux tubes of magnetic field. For prokaryotes the replication of chromosomes is followed by the fission of the cell membrane. Also plant nuclei separated by cellulose walls suffer fission after the replication of chromosomes. For animals nuclear membranes break down before the replication suggesting that nuclear TQC programs are reset and newly formed nuclei start TQC from a clean table. For eukaryotes cell division is controlled by centrosomes [I7]. The presence of centrosomes is not necessary for the survival of the cell or its replication but is necessary for the survival of multicellular. This conforms with the proposed picture.

2. If the conjugate strands are specialized in TQC, the formation of new double strands does not involve braids in an essential manner. The formation of conjugate strand should lead to also to a generation of braid strands unless they already exist as strands connecting DNA and its conjugate and are responsible for "printing". These strands need not be short. The braiding associated with printing would be hardware program which could be genetically determined or at least inherited as such so that the strands should be restricted inside the inner cell membrane or at most traverse the inner nuclear membrane and turn back in the volume between inner membrane and endoplasmic reticulum.

   The return would be most naturally from the opposite side of nuclear membrane which suggest a breaking of rotational symmetry to axial symmetry. The presence of centriole implies this kind of symmetry breaking: in neurons this breaking becomes especially obvious. The outgoing braid strands would be analogous to axon and returning braid strands to dendrites. Inner nuclear membrane would decompose the braiding to three parts: one for strand, second for conjugate strand, and a part in the empty space inside nuclear envelope.

3. The formation of new DNA strands requires recognition relying on "strand color" telling which nucleotide can condense at it. The process would conserve the braidings connecting DNA to the external world. The braidings associated with the daughter nuclei would be generated from the braiding between DNA and its conjugate. As printing software they should be identical so that the braiding connecting DNA double strands should be a product of a braiding and its inverse. This would however mean that the braiding is trivial. The division of the braid to three parts hinders the transformation to a trivial braid if the braids combine to form longer braids only during the "printing" activity.

4. The new conjugate strands are formed from the old strands associated with printing. In the case of plants the nuclear envelope does not disintegrate and splits only after the replication of chromosomes. This would suggest that plant cells separated by cell walls perform only intracellular TQC. Hermits do not need social skills. In the case of animals nuclear envelope disintegrates. This is as it must be since the process splits the braids connecting strand and conjugate strands so that they can connect to the cell membrane. The printing braids are inherited as such which conforms with the interpretation as a fixed software.

5. The braids connecting mother and daughter cells to extranuclear world would be different and TQC braidings would give to the cell a memory about its life-cycle. The age ordering of cells would have the architecture of a tree defined by the sequence of cell replications and the life history of the organism. The 4-D body would contain kind of log file about TQC performed during life time: kind of fundamental body memory.

6. Quite generally, the evolution of TQC programs means giving up the dogma of genetic determinism. The evolution of TQC programs during life cycle and the fact that half of them is inherited means kind of quantum Lamarckism [I31]. This inherited wisdom at DNA level might partly explain why we differ so dramatically from our cousins.

4.8.2 Sexual Reproduction And TQC

Meiosis [I35] produces gametes in which the pair of chromosomes from parents is replaced with single chromosome obtained as chimera of the chromosomes of parents. Meiosis is the basic step of sexual reproduction and it is interesting to study it from TQC point of view.

1. Sexual reproduction of eukaryotes relies on haploid cells differing from diploid cells in that chromatids do not possess sister chromatids. Whereas mitosis produces from single diploid [I52] cell two diploid cells, meiosis gives rise to 4 haploid [I52] cells. The first stage is very much like mitosis. DNA and chromosomes duplicate but cell remains a diploid in the sense that there is only single centrosome: in mitosis also centrosome duplicates. After this the cell membrane divides into two. At the next step the chromosomes in daughter cells split into two sister chromosomes each going into its own cell. The outcome is four haploid cells.

2. The presence of only single chromatid [I9] in haploids means that germ cells would perform only one half of the "social" TQC performed by soma cells [I58] who must spend their life cycle as a member of cell community. In some cells the TQC would be performed by chromatids of both father and mother making perhaps possible kind of stereo view about world and a model for couple - the simplest possible social structure.

3. This brings in mind the sensory rivalry between left and right brain: could it be that the two TQC's give competing computational views about world and how to act in it? We would have inside us our parents and their experiences as a pair of chromatids representing chemical chimeras of chromatid pairs possessed by the parents: as a hardware - one might say. Our parents would have the same mixture in software via sharing and fusion of chromatid mental images or via quantum computational rivalry. What is in software becomes hardware in the next generation.¡/p¿¡p¿

4. The ability of sexual reproduction to generate something new relates to meiosis. During meiosis genetic recombination [I23] occurs via chromosomal crossover which in string model picture would mean splitting of chromatids and the recombination of pieces in a new manner $(A_1 + B_1) + (A_2 + B_2) \to (A_1 + B_2) + (A_2 + B_1)$ takes place in crossover and $(A_1 + B_1 + C_1) + (A_2 + B_2 + C_2) \to (A_1 + B_2 + C_1) + (A_2 + B_1 + C_2)$ in double crossover. New hardware for TQC would result by combining pieces of existing hardware. What this means in terms of braids should be clarified.

5. Fertilization is in well-define sense the inverse of meiosis. In fertilization the chromatids of spermatozoa and ova combine to form the chromatids of diploid cell. The recombination of genetic programs during meiosis becomes visible in the resulting TQC programs.

4.8.3 What Is The Role Of Centrosomes And Basal Bodies?

Centrosomes [I7] and basal bodies [I4] form the main part of Microtubule Organizing Center [I37]. They are somewhat mysterious objects and at first do not seem to fit to the proposed picture in an obvious manner.

1. Centrosomes consist two centrioles [I6] forming a T shaped antenna like structure in the center of cell. Also basal bodies consist of two centrioles but are associated with the cell membrane. Centrioles and basal bodies have cylindrical geometry consisting of nine triplets of microtubules along the wall of cylinder. Centrosome is associated with nuclear membrane during mitosis.

2. The function of basal bodies which have evolved from centrosomes seems to be the motor control (both cilia [I11] and flagella [I21]) and sensory perception (cilia). Cell uses flagella and cilia to move and perceive. Flagella and cilia are cylindrical structures associated with the basal bodies. The core of both structures is axoneme having $9 \times 2 + 2$ microtubular structure. So called primary cilia do not posses the central doublet and the possible interpretation is that the inner doublet is involved with the motor control of cilia. Microtubules [I36] of the pairs are partially fused together.

3. Centrosomes are involved with the control of [I39] [I39]. Mitosis can take place also without them but the organism consisting of this kind of cells does not survive. Hence the presence of centrosomes might control the proper formation of TQC programs. The polymerization of microtubules [I36] is nucleated at microtubule self-organizing center which can be centriole or basal body. One can say that microtubules which are highly dynamical structures whose length is changing all the time have their second end anchored to the self-organizing center. Since this function is essential during mitosis it is natural that centrosome controls it.

4. The key to the understanding of the role of centrosomes and basal bodies comes from a paradox. DNA and corresponding TQC programs cannot be active during mitosis. What does then control mitosis?

   (a) Perhaps centrosome and corresponding TQC program represents the analog of the minimum seed program in computer allowing to generate an operating system like Windows 2000 (the files from CD containing operating system must be read!). The braid strands going through the microtubules of centrosome might define the corresponding TQC program. The isolation from environment by the microtubular surface might be essential for keeping the braidings defining these programs strictly unchanged.

   (b) The RNA defining the genome of centrosome (yes: centrosome has its own genome defined by RNA rather than DNA [I7] !) would define the hardware for this TQC. The basal bodies could be interpreted as a minimal sensory-motor system needed during mitosis.

   (c) As a matter fact, centrosome and basal bodies could be seen as very important remnants of RNA era believed by many biologists to have preceded DNA era. This assumption is also made in TGD inspired model of prebiotic evolution [**?**].

   (d) Also other cellular organelles possessing own DNA and own TQC could remain partly functional during mitosis. In particular, mitochondria are necessary for satisfying energy needs during the period when DNA is unable to control the situation so that they must have some minimum amount of own genome.

5. Neurons [I40] do not possess centrosome which explains why they cannot replicate. The centrioles are replaced with long microtubules associated with axons and dendrites. The system consisting of microtubules corresponds to a sensory-motor system controlled by the TQC programs having as a hardware the RNA of centrosomes and basal bodies. Also this system would have a multicellular part.

6. Intermediate filaments [I27], actin filaments [I3], and microtubules [I36] are the basic building elements of the eukaryotic cytoskeleton [I14]. Microtubules, which are hollow cylinders with outer radius of 24 nm, are especially attractive candidates for structures carrying bundles of braid strands inside them. The microtubular outer-surfaces could be involved with signalling besides other well-established functions. It would seem that microtubules cannot be assigned with TQC associated with nuclear DNA but with RNA of centrosomes and could contain corresponding braid strand bundles. It is easy to make a rough estimate for the number of strands and this would give an estimate for the amount of RNA associated with centrosomes. Also intermediate filaments and actin filaments might relate to cellular organelles having their own DNA.

4.9 Indirect Evidence For The DNA As Topological Quantum Computer Model

There is a profound revolution taking place in genetics [I111]. It is fair to say that genetic determinism is falling down and the revolution that is waiting just around the corner will be more profound that anything that has taken place before this in biology. The term "genome's dark matter" expresses what has been discovered during last years. The motivation for the term is the strong analogy with the dark matter of physics. In TGD framework this analogy might be much more than analogy.

The basic anomalies discussed in the article are following.

1. Trans-generational inheritance [I115, I124]. The stretches of DNA which were present in parent's or grand parents' genome but are not present in the genome of offspring affect the traits of offspring.

2. Context sensitivity of gene's effect: the effect of gene is highly sensitive on its environment in DNA.

3. Genes explain in many cases only 10 percent of the disease's inheritability: this is "missing heritability" problem [I85].

It is interesting to try to interpret these results in the framework provided by the model of DNA as topological quantum computer. It is good to summarize the basic ideas and concepts behind the model.

4.9.1 The Notion Of Magnetic Body

The notion of magnetic body as intentional agent using biological body as a motor instrument and sensory receptor with communications taking place in terms of fractal generalization of EEG is the key idea. Each physical system consisting of matter has magnetic body. Magnetic body of given living organism has a fractal onion like structure with layer sizes varying from sub-cellular scales to the scales assignable to EEG frequencies (Earth size) and even above up to the scale of light-life and maybe beyond to scales characterizing the evolution of species.

Immediate implications are the notion of collective DNA expression made possible by the interaction of DNA strands so that they belong to magnetic flux sheets: in this manner not only DNAs of cells and organelles, organs, single organism but also groups of organisms can form coherent structures expressing themselves in synchronous manner. This is a testable prediction.

4.9.2 DNA As Topological Quantum Computer

Topological quantum computation is based on braiding: various braiding patterns for braid strands define the TQC programs. There are two types of braids: time-like and space-like.

1. Cell membrane is 2-D liquid and the flow of lipids affected by the flow of cellular liquid and also by nerve pulse patterns in case of neurons induce braiding. This braiding takes place dynamically at the 2-D parquette defined by the cell membrane in time direction and dance metaphor applies to it. Running TQC program can be seen as dancing.

2. The magnetic flux tubes connecting DNA nucleotides to the lipids of nuclear membrane and cell membrane and possibly also to membranes of other cells define the space-like braid strands. Since the flux tubes connected to DNA strands are like threads connecting the feet of dancers to the walls of the dance hall the resulting space-like braiding codes TQC program to memory, which is highly robust as a topological invariant.

There is a kind of duality between time-like and space-like braidings. This is a new element to the conventional quantum computation paradigm. Combined with the idea that memories are stored in geometric past in zero energy ontology this gives an extremely elegant memory storage mechanism.

4.9.3 Implications For Genetics

This vision has profound implications for genetics.

1. Genes define only the hardware of TQC. Software is defined by the braidings. Introns whose portion steadily increases as the evolutionary level becomes higher and is more than 95 per cent in humans, have been traditionally interpreted as junk DNA. In this framework introns correspond naturally to that part of genome specialized in TQC: from the point of view of TQC it does matter much whether the intronic portions correspond to repeating sequences (interpreted as a signal for "junkness") or not.

2. The evolution of topological quantum computation programs would be far more important than the evolution of genome and the huge differences between species with almost the same genome (such as we and our cousins) could be understood in terms ofw hat at our level of hierarchy corresponds to cultural evolution due to the evolution of topological quantum computer programs. The evolution would have been for a long time evolution of TQC programs rather than that of hardware as the fact that the size of genome and details of does not matter much suggests. The appearance of of prokaryotes (and multi-cellulars) meant the emergence of introns and perhaps also the precedessor of cultural evolution as the evolution of quantum software and collective magnetic bodies.

4.9.4 Implications For Mendelian Anomalies

This vision also suggests how to understand the origin of the Mendelian anomalies.

1. Trans-generational inheritance might be understood as an inheritance of TQC programs carrying indirectly information also about the genome of parents. If one accepts TGD vision about organisms as 4-D structures, one must of course be ready to even ask whether genetic effects could be also take place via the mediation of the magnetic bodies assignable to structures formed by several generations.

   Of course, it is far from clear what the mechanism leading to the inheritance of TQC programs could mean. Does it make sense to speak about magnetic body for causal diamonds (CDs) in time scale of several generations? Could TQC programs associated with the magnetic bodies affect also the future generations by signals realized in terms of positive and negative energy photons propagating in opposite time directions? In zero energy ontology (ZEO) instantaneous communications realized as time reflections are indeed possible and are central in the realization of memories and anticipation in TGD Universe.

2. The context sensitivity of the effect of particular gene could be understood in this picture since the programs are determined not only by a single gene but longer portions of DNA. Individual genes do not matter much when one tries to understand genetic correlates for autism, schizophrenia, and other complex diseases related to functions rather than mere structure. If one speaks about structure, such as the color of flowers situation is of course very simple and Mendelian approach works well. An interesting question is how closely the structure-function dichotomy, exon-intron dichotomy and hardware-software dichotomy correspond to each other.

3. High level diseases would be much more programming errors than hardware problems. This would solve "missing heritability" problem.

What is amusing, that the physicist's dark matter would be behind "genome's dark matter": magnetic flux tubes are assumed to be carriers of dark matter- dark quarks in fact. In the proposed model quarks with large Planck constant meaning that their Compton length scales is scaled up and gives them size scale of order cell at least are in key role!

4.10 How To Build A Quantum Computer From Magnetic Flux Tubes

Magnetic flux tubes play a key role in TGD inspired model of quantum biology. Could the networks of magnetic flux tubes containing dark particles with large $\hbar$ in macroscopic quantum states and carrying beams of dark photons define analogs of electric circuits? This would be rather cheap technology since no metal would be needed for wires. Dark photon beams would propagate along the flux tubes representing the analogs of optical cables and make possible communications with maximal signal velocity.

I have actually made much more radical proposal in TGD inspired quantum biology. According to this proposal, flux tube connections are dynamical and can be changed by reconnection of two magnetic flux tubes. The signal pathways $A \to C$ and $B \to D$ would be transformed to signal pathways to $A \to D$ and $B \to C$ by reconnection. Reconnection actually represents a basic

stringy vertex. The contraction of magnetic flux tubes by a phase transition changing Planck constant could be fundamental in bio-catalysis since it would allow distant molecules connected by flux tubes to find each other in the molecular crowd.

DNA as a topological quantum computer is the idea that I have been developing for 5 years or so. I have concentrated on the new physics realization of braids and devoted not much thought to how the quantum computer problems might run in this framework. I was surprised to realize how little I know about what happens in even ordinary computation. Instead of going immediately to Wikipedia I take the risk of publicly making myself fool and try to use my own brain.

4.10.1 What Can One Learn From Ordinary Computer Programs

One could begin with the question what happens in classical computation. How the program is realized and how it runs? The notion of Turing machine (see `http://tinyurl.com/7c4kl`) represents an extreme abstraction mentioning nothing about the technical side and does not help much in attempts to answer these questions. Turing paradigm also assumes that program is a temporal sequence of operations. These operations could however correspond to a linear spatial sequences and inputs and outputs in this case would correspond to boundary values at the ends of the linear structure. This requires that the dynamics is such that evolution in spatial direction is analogous to a deterministic time evolution. In this case it is much easier to imagine biological realizations of quantum computer programs in TGD inspired bio-world.

To develop concrete ideas, one can start from the picture provided by ordinary computer program.

1. Programs consist of temporal/spatial sequences of commands and commands represent basic functions from which one can build more complex functions by the composition of functions having some numbers of input and output arguments. The eventual output variable can be expressed by printing of a piece of text or as an image in the computer screen. Each step in the program corresponds to a composition of functions: $f_{n+1} = g_{n+1} \circ f_n$. There is some minimal set of primitive/prime functions from which one builds up more complex functions by composition.

2. How this is realized at the level of hardware? One can assume that the basic functions are at some fixed places in the computer memory having addresses given by integers represented as bit sequences. This address represents the command - a name of the function. The names for input variables and output variables are bit sequences giving the addresses of the places containing the values of these variables. Program is a sequence of commands represented as bit sequences giving the address of the function to be computed at a given step and the addresses of inputs and outputs. As the processing unit reads the command, it generates/activates connections from the addresses of inputs to the address representing the function and from this address to the addresses of outputs.

   Essentially the challenge is to reconnect, build/activate connections. An interesting question is whether learning identified as strengthening of synaptic connections (see `http://tinyurl.com/cn7724o`) [J4] is one particular example of this process.

3. How the sequence of bits representing command address is realized? As the processing unit reads the address of command it should automatically create/activate a connection from this address to the command address. The connections from the processing unit to the addresses could exist physically as wirings.

4. It is not necessary that program is dynamical so that the inputs and outputs would be initial and final values of variables. Inputs and outputs could also correspond to values of variables at the ends of a linear structure. In topological quantum computation space-like entanglement would represent superposition of input-output pairs characterizing a function as a rule with instances represented as instances appearing in the superposition.

If this picture is roughly correct, re-connection would be the basic process. Reconnection is the basic process for magnetic flux tubes and ADP$\leftrightarrow$ ATP has been assigned to this process with ATP molecule serving as a relay activating the flux tube connection. Maybe ADP-ATP process,

which is usually seen as a basic step of metabolism, could be seen as the core step for quantum computation performed by living matter. One expects that the presence ATP makes the rule represented by negentropic quantum entanglement conscious.

4.10.2 Quantum Computation Magnetic Flux Tubes As Connections

Consider now quantum computation could take place in a circuitry having magnetic flux tubes as wires and some bio-molecules of groups of them as units defining prime functions. DNA as topological quantum computer could be taken as a starting point. The outcome of quantum computation is determined statistically as ensemble average so that a large number of copies of the program should be present and realized in terms of groups of cells or molecules connected by braidings if the quantum computation is space-like. This option seems more natural than time-like quantum computation realized as a 2-D liquid flow of lipids in the lipid layers of the cell membrane.

The hardware

Consider first the hardware of topological quantum computation using space-like braids.

1. Magnetic flux tubes would represent the wires along which inputs and outputs travel in the case of classical computation or dynamical quantum computation. In the case of space-like topological quantum computation entanglement is between the ends of the flux tubes.

2. Variables could be represented in many ways. For space-like quantum computations they could correspond to spin states of dark electrons at flux tubes or to polarization states of dark electrons at the flux tubes. In the original model of DNA as topological quantum computer quarks and antiquarks where proposed as a representation of genetic codons: also this quite science fictive option could make sense in TGD Universe since TGD predicts scaled versions of QCD like dynamics and presence of elementary particles in several p-adic scales and in scales dictated by value of Planck constant for given p-adic length scale.

   The spin states of electron pair has been proposed as one possible representation of the 4 genetic codons. Quantum variables would be represented by qubit sequences and the measurement of qubit would give a bit sequence characterizing the classical value of the variable. Bio-molecules would be natural places for storing the values of the variables. For dynamical computations the values of variables could be transmitted using dark photons.

3. There would exist basic processing units calculating the prime functions from which more complex functions would be obtained as composites. Basic units could correspond to bio-molecules. In the case of classical computation the inputs to molecules and outputs from them would travel along the flux tubes. In quantum computation these signals could be used to control the initial values of the variables. Molecules could also serve as gates for quantum computation.

Representation of programs

The basic program units in the case of quantum computation would be represented by braidings.

1. If the ends of braid strands are able to move freely when needed, it becomes possible to re-write programs. Lipid layers of cell membrane can be in liquid crystal state so that these are ideal for this purpose. The time-like braiding resulting from lipid flow and representing running topological quantum computation program would induce space-like braiding representing space-like topological quantum computation or a rule. A particular quantum computer program represented as space-like braiding of the flux tubes would result as liquid crystal melts for a moment and freezes again.

   The process (see `http://tinyurl.com/yarrblxn`) in which proteins covered by ordered water analogous to ice temporarily melt and form aggregates [I56] is basic process induced by the feed of energy to the cellular system and could be compared to cellular summer. This process could mean quite generally molecular re-programming induced by the flow of cellular water inducing molecular flows inducing re-braidings. The braiding would also store the

highlights of the cellular summer to cellular memory! This could be also seen learning by a modification of various quantum computer programs.

2. Negentropic entanglement (see **Fig.** `http://tgdtheory.fi/appfigures/cat.jpg` or **Fig. ??** in the appendix of this book) is highly suggestive and would conform with the idea that the rule represented by entanglement represents conscious information or information which can become conscious. The process of becoming conscious information could involve ATP→ ADP and de-activating the flux tube and destroy the information. Time-like braiding represented by liquid flow would modify space-like braiding.

   It is not quite clear whether the information is conscious when negentropic entanglement (and ATP) is present - as Bohm's notion of active information (see `http://tinyurl.com/qhx3suy`) [J29] would suggest - or when ATP is transformed to ADP and connection becomes passive. Negentropic entanglement can be stable with respect to NMP [K60] so that the presence of ATP could mean period of conscious experience - negentropic entanglement could be analogous to active information.

   TGD based model for the memory recall by sending negative energy signals to geometric past suggests that the absorption of negative energy photon transforms ATP to ADP. Conscious experience is regenerated in the geometric now where the negative energy signal came from - perhaps by transforming ADP to ATP by using the negative resulting by sending of negative energy signal! Conscious reading would be actually memory recall and analogous to teleportation? The destruction of the representation of memory in the geometric past would have interpretation in terms of no-cloning theorem (see `http://tinyurl.com/2dhl4oe`) [B3].

3. Static realizations of the programs are easier to imagine since no temporal codes are needed for the transfer of bits. An attractive idea is that the computations are represented by static entanglements for linear structures and that time-like braiding allows to modify the programs.

The realization of program

The program would be basically a sequence of address lists. Address list would contain the address of the function to be performed and the addresses of the input molecules and output molecules. How to represent the address physically?

1. The simplest manner to realize this would use existing flux tubes connecting the processing unit to all possible input and output addresses as well as command addresses, and activate those flux tubes to which input and output data are assigned and reconnect them to the flux tubes connecting processing unit to the unit representing the function. The processing unit would have flux tubes coming from all possible inputs, going to all possible outputs, flux tubes going to places representing functions and coming from these places. Processing unit would be like a relay station or old fashioned telephone center whose sole purpose would be to create connections by reconnecting flux tubes. ATP molecule would be probably involved with the activation and - allowing a sloppy language - one could say that communication line becomes conscious when ATP is attached to it.

   (a) Addressing would be just selection of activated molecules and analogous to that used in telephone network or computer network connected by cables. This would require static flux tube network and flux tubes could be either active or passive. In passive state flux tubes could be short-cut by a reconnection with hydrogen bond so that the ends of cut flux tube would end up to water molecules. This is however not necessary. Activation in absence of the short cut would involve reconnection of a flux tube with a flux tube connecting two parts of ATP - possibly hydrogen bond again- so that ATP becomes part of the flux tubes. If also short cut is involved, the strands coming to the two water molecules reconnect and generate hydrogen bond and flux tube to which ATP would attach in the proposed manner. As ATP is used it transforms to ADP and de-attaches from the flux tube.

(b) One can imagine also a dynamical addressing based on the generation of magnetic flux tubes between inputs and submodules. The computational process could be still space-like. The first manner to realize dynamical addressing would be by attaching to the ends of dynamical flux tubes biomolecules, which bind to specific receptors. Receptor mechanism would allow to connect distant cells to each other and build a magnetic flux tube connection between them. Computational unit specialized to run a specific program could excrete biomolecules binding to the input and output receptors: this program would realized function in terms of space-like entanglement. Glands (see `http://tinyurl.com/cxjro9z`) excrete hormones binding to receptors and various glands could in principle serve as computational units. Various information molecules bind very selectively and this might also relate to quantum space-like computations.

(c) Second mechanism of dynamical addressing would use dark photons. In this case resonant interaction selecting the target would replace the receptor mechanism. In this kind of situation one can claim that flux tubes are un-necessary, one can use just resonance to build connection to a desired place just as one does in radio communications. Of course, topological light rays could be accompanied by flux tubes. For instance, DNA nucleotide could attach by flux tube to its conjugate in distant DNA molecule and if the connection is based on resonance only similar nucleotide sequences could connect with each other. I have discussed this kind of mechanism in a model for remote replication of DNA (see `http://tinyurl.com/ybvosy7h`) [K114] based on the experimental work by Peter Gariaev and his group. The resonance mechanism could also make possible to establish flux tube connections and the quantum computation could be a static operation.

2. DNA as topological quantum computer vision gives some idea about how the computer program could be realized as a spatial linear structure.

   (a) Program would be a sequence of topological quantum computations. Given topological quantum computation would be represented by a braiding of flux tubes connecting DNA nucleotides with the lipid molecules of the inner lipid layer. Program would correspond to a linear sequence of cells with the outer lipid layer connected to the DNA of the second cell.

   (b) Lipid flows at given lipid layer could be used to rewrite programs and the programs could respond to the changes in environment in this manner: this would require that the lipid layer is in liquid crystal state during the period when program is changed. Also nerve pulse patterns would induce these flows. Programs would also represent memories as rules realized as quantum abstractions or as quantum functions.

   (c) The program would "run" in the spatial direction. The selection of active input and output variables would be by acting the connection from molecule in question by attaching ATP as a relay through which the reconnected flux tube would traverse. This would be also part of the writing of the program. The superposition of entangled inputs and outputs could be seen as a quantum superposition of classical programs assigning outputs to inputs. Also microtubule-lipid layer braiding suggested also to play a key role in the realization of memories could give rise to similar space-like quantum computation representing rules.

   (d) The effective 2-dimensionality implied by strong form of holography implied in turn by strong form of general coordinate invariance means that the physics depends on partonic 2-surfaces and 4-D tangent space data at them. This suggests that the dynamics on space-like 3-surfaces and light-like orbits of partonic 2-surfaces is fixed by a process analogous to gauge selection. Does just this effective gauge symmetry make possible to write quantum computer programs? Already ordinary deterministic computer program means selection of one particular dynamics from several alternative options suggesting that strict determinism is broken.

3. What could be the role of bio-catalysis in the computation? Bio-catalysis is a central part of the biological information processing and it would not be surprising if the catalysts connected

by flux tubes to substrate molecules were involved with the computations. An attractive idea is that various information molecules binding to receptors involved with bio-control (neurotransmitters, hormones, etc...) are involved with building the flux tube connections between cells. These bio-molecules could carry the ends of flux tubes to special places for which receptors serve as addresses and in this manner build hardware for topological quantum computation involving inputs and outputs in distant parts of the body. The final output could be transformed to controlled gene expression. Quite generally, catalysts bind very selectively and could play a role similar that played by information molecules in building up the quantum computer programs.

4. One can imagine also purely classical computation based on catalytic mechanism probably allowing generalization to quantum case. The idea is that computer program - understood now as dynamical structure - is analogous to what happens in fairy tale in which hero finds a key which fits to a lock of a room containing a key which... There exists a beautiful realization of classical computation in terms of chemical concentrations using DNA. The output of given reaction representing computational step appears in the next reaction provide the system contains additional participating molecules, which could be both substrate molecules and catalysts. The program could be represented as concentrations of molecules needed at intermediate steps and lock-to-key mechanism guarantees that they are performed in the correct temporal order. Inputs and output molecules could be connected by flux tubes to bio-molecules which bind to specific receptors associated with the molecule representing the particular subprogram. This would automatically create a large number of classical computations proceeding in fixed order, maybe even quantum computations.

4.11 Appendix: A 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 described. This view has developed much before the original version of this chapter was written.

The original idea was that the proposed modification of the embedding space could explain naturally phenomena like quantum Hall effect involving fractionization of quantum numbers like spin and charge. This does not however seem to be the case. $G_a \times G_b$ implies just the opposite if these quantum numbers are assigned with the symmetries of the embedding space. For instance, quantization unit for orbital angular momentum becomes n_a where Z_{n_a} is the maximal cyclic subgroup of G_a.

One can however imagine of obtaining fractionization at the level of embedding space for space-time sheets, which are analogous to multi-sheeted Riemann surfaces (say Riemann surfaces associated with $z^{1/n}$ since the rotation by 2π understood as a homotopy of M^4 lifted to the space-time sheet is a non-closed curve. Continuity requirement indeed allows fractionization of the orbital quantum numbers and color in this kind of situation.

4.11.1 Both Covering Spaces And Factor Spaces Are Possible

The observation above stimulates the question whether it might be possible in some sense to replace H or its factors by their multiple coverings.

1. This is certainly not possible for M^4, CP_2, or H since their fundamental groups are trivial. On the other hand, the fixing of 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 a 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. Zero energy ontology forces to modify this picture somewhat. In zero energy ontology causal diamonds (CDs) defined as the intersections of future and past directed light-cones are loci

for zero energy states containing positive and negative energy parts of state at the two light-cone boundaries. The location of CD in M^4 is arbitrary but p-adic length scale hypothesis suggests that the temporal distances between tips of CD come as powers of 2 using CP_2 size as unit. Thus M^4 is replaces by CD and $\hat{M}^4$ is replaced with $\hat{CD}$ defined in obvious manner.

3. H_4 represents a straight cosmic string inside CD. Quantum field theory phase corresponds to Jones inclusions with Jones index $\mathcal{M} : \mathcal{N} < 4$. Stringy phase would by previous arguments correspond to $\mathcal{M} : \mathcal{N} = 4$. Also these Jones inclusions are labeled by finite subgroups of $SO(3)$ and thus by Z_n identified as a maximal Abelian subgroup.

   One can argue that cosmic strings are not allowed in QFT phase. This would encourage the replacement $\hat{CD} \times \hat{CP}_2$ implying that surfaces in $CD \times S^2$ and $(M^2 \cap CD) \times CP_2$ are not allowed. In particular, cosmic strings and CP_2 type extremals with M^4 projection in M^2 and thus light-like geodesic without zitterwebegung essential for massivation are forbidden. This brings in mind instability of Higgs=0 phase.

4. The covering spaces in question would correspond to the Cartesian products $\hat{CD}_{n_a} \times \hat{CP}_{2n_b}$ of the covering spaces of $\hat{CD}$ and $\hat{CP}_2$ by Z_{n_a} and Z_{n_b} with fundamental group is $Z_{n_a} \times Z_{n_b}$. One can also consider extension by replacing $M^2 \cap CD$ and S^2 with its orbit under G_a (say tetrahedral, octahedral, or icosahedral group). The resulting space will be denoted by $\hat{CD}\hat{\times}G_a$ *resp.* $\hat{CP}_2\hat{\times}G_b$.

5. One expects the discrete subgroups of $SU(2)$ emerge naturally in this framework if one allows the action of these groups on the singular sub-manifolds $M^2 \cap CD$ 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 correspond to exceptional groups in the ADE correspondence). For instance, in the case of $M^2 \cap CD$ 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.

6. Also the orbifolds $\hat{CD}/G_a \times \hat{CP}_2/G_b$ can be allowed as also the spaces $\hat{CD}/G_a \times (\hat{CP}_2\hat{\times}G_b)$ and $(\hat{CD}\hat{\times}G_a) \times \hat{CP}_2/G_b$. Hence the previous framework would generalize considerably by the allowance of both coset spaces and covering spaces.

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 $(M^2 \cap CD) \times CP_2$ takes place? It would seem that the covariant metric of M^4 factor proportional to $\hbar^2$ must be discontinuous at the singular manifold since only in this manner the idea about different scaling factor of M^4 metric can make sense. This is consistent with the identical vanishing of Chern-Simons action in $M^2 \times S^2$.

2. One might worry whether the phase transition changing Planck constant means an instantaneous change of the size of partonic 2-surface in CD degrees of freedom. This is not the case. Light-likeness in $(M^2 \cap CD) \times S^2$ makes sense only for surfaces $X^1 \times D^2 \subset (M^2 \cap CD) \times S^2$, 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 $(M^2 \cap CD) \times S^2$ irrespective of the value of Planck constant requires that X^2 has single point of $(M^2 \cap CD)$ 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_I^2 of CP_2 can be deformed to that of S_{II}^2 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) and classical light-like homotopies (cobordisms) are very relevant for the understanding of phase transitions changing Planck constant.

4.11.2 Do Factor Spaces And Coverings Correspond To The Two Kinds Of Jones Inclusions?

What could be the interpretation of these two kinds of spaces?

1. Jones inclusions appear in two varieties corresponding to $\mathcal{M} : \mathcal{N} < 4$ and $\mathcal{M} : \mathcal{N} = 4$ and one can assign a hierarchy of subgroups of $SU(2)$ with both of them. In particular, their maximal Abelian subgroups Z_n label these inclusions. The interpretation of Z_n as invariance group is natural for $\mathcal{M} : \mathcal{N} < 4$ and it naturally corresponds to the coset spaces. For $\mathcal{M} : \mathcal{N} = 4$ the interpretation of Z_n has remained open. Obviously the interpretation of Z_n as the homology group defining covering would be natural.

2. $\mathcal{M} : \mathcal{N} = 4$ should correspond to the allowance of cosmic strings and other analogous objects. Does the introduction of the covering spaces bring in cosmic strings in some controlled manner? Formally the subgroup of $SU(2)$ defining the inclusion is $SU(2)$ would mean that states are $SU(2)$ singlets which is something non-physical. For covering spaces one would however obtain the degrees of freedom associated with the discrete fiber and the degrees of freedom in question would not disappear completely and would be characterized by the discrete subgroup of $SU(2)$.

   For anyons the non-trivial homotopy of plane brings in non-trivial connection with a flat curvature and the non-trivial dynamics of topological QFTs. Also now one might expect similar non-trivial contribution to appear in the spinor connection of $\hat{CD}\hat{\times}G_a$ and $\hat{CP}_2\hat{\times}G_b$. In conformal field theory models non-trivial monodromy would correspond to the presence of punctures in plane.

3. For factor spaces the unit for quantum numbers like orbital angular momentum is multiplied by n_a *resp.* n_b and for coverings it is divided by this number. These two kind of spaces are in a well defined sense obtained by multiplying and dividing the factors of $\hat{H}$ by G_a *resp.* G_b and multiplication and division are expected to relate to Jones inclusions with $\mathcal{M} : \mathcal{N} < 4$ and $\mathcal{M} : \mathcal{N} = 4$, which both are labeled by a subset of discrete subgroups of SU(2).

4. The discrete subgroups of $SU(2)$ with fixed quantization axes possess a well defined multiplication with product defined as the group generated by forming all possible products of group elements as elements of $SU(2)$. This product is commutative and all elements are idempotent and thus analogous to projectors. Trivial group G_1, two-element group G_2 consisting of reflection and identity, the cyclic groups Z_p, p prime, and tetrahedral, octahedral, and icosahedral groups are the generators of this algebra.

By commutativity one can regard this algebra as an 11-dimensional module having natural numbers as coefficients ("rig"). The trivial group G_1, two-element group G_2¡ generated by reflection, and tetrahedral, octahedral, and icosahedral groups define 5 generating elements for this algebra. The products of groups other than trivial group define 10 units for this algebra so that there are 11 units altogether. The groups Z_p generate a structure analogous to natural numbers acting as analog of coefficients of this structure. Clearly, one has effectively 11-dimensional commutative algebra in 1-1 correspondence with the 11-dimensional "half-lattice" N^{11} (N denotes natural numbers). Leaving away reflections, one obtains N^7. The projector representation suggests a connection with Jones inclusions. An interesting question concerns the possible Jones inclusions assignable to the subgroups containing infinitely manner elements. Reader has of course already asked whether dimensions 11, 7 and their difference 4 might relate somehow to the mathematical structures of M-theory with 7 compactified dimensions. One could introduce generalized WCW

spinor fields in the WCW labelled by sectors of H with given quantization axes. By introducing Fourier transform in N^{11} one would formally obtain an infinite-component field in 11-D space.

The question how do the Planck constants associated with factors and coverings relate is far from trivial and I have considered several options.

1. 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 metric allowed by Weyl invariance of Kähler action by dividing metric with $\hbar^2(CP_2)$, one obtains $r^2 \equiv \hbar^2/\hbar_0^2\hbar^2(M^4)/\hbar^2(CP_2)$. This puts M^4 and CP_2 in a very symmetric role and allows much more flexibility in the identification of symmetries associated with large Planck constant phases.

2. Algebraist would argue that Planck constant 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. This gives two options.

3. Option I: $r(X) = n$ for covering and $r(X) = 1/n$ for factor space gives $r \equiv \hbar/\hbar_0 = r(M^4)/r(CP_2)$. This gives $r = n_a/n_b$ for $\hat{H}/G_a \times G_b$ option and $r = n_b/n_a$ for $\hat{H}\hat{times}(G_a \times G_b)$ option with obvious formulas for hybrid cases.

4. Option II: $r(X) = 1/n$ for covering and $r(X) = n$ for factor space gives $r = r(CP_2)/r(M^4)$. This gives $r = n_b/n_a$ for $\hat{H}/G_a \times G_b$ option and $r = n_a/n_b$ for $\hat{H}\hat{times}(G_a \times G_b)$ option with obvious formulas for the hybrid cases.

5. At quantum level the fractionization would come from the modification of fermionic anticommutation (bosonic commutation) relations involving $\hbar$ at the right hand side so that particle number becomes a multiple of $1/n$ or n. If one postulates that the total number states is invariant in the transition, the increase in the number of sheets is compensated by the increase of the fundamental phase space volume proportional to $\hbar$. This would give $r(X) \to r(X)/n$ for factor space and $r(X) \to nr(X)$ for the covering space to compensate the n-fold reduction/increase of states. This would favor Option II.

6. The second manner to distinguish between these two options is to apply the theory to concrete physical situations. Since G_a and G_b act as symmetries in CD and CP_2 degrees of freedom, one might of being able to distinguish between the two options if it is possible to distinguish between the action of G as symmetry of quantum states associated with covering and factor space. Also the quantization of the orbital spin quantum number at single particle level as multiples of n can be distinguished from that in multiples of $1/n$.

4.11.3 A Simple Model Of Fractional Quantum Hall Effect

The generalization of the embedding space suggests that it could possible to understand fractional quantum Hall effect [D1] at the level of basic quantum TGD. This section represents the first rough model of QHE constructed for a couple of years ago is discussed. Needless to emphasize, the model represents only the basic idea and involves ad hoc assumption about charge fractionization.

Recall that the formula for the quantized Hall conductance is given by

$$\begin{aligned} \sigma &= \nu \times \frac{e^2}{h} \ , \\ \nu &= \frac{n}{m} \ . \end{aligned} \tag{4.11.1}$$

Series of fractions in $\nu = 1/3, 2/5, 3/7, 4/9, 5/11, 6/13, 7/15...$, $2/3, 3/5, 4/7, 5/9, 6/11, 7/13...$, $5/3, 8/5, 11/7, 14/9...4/3, 7/5$ $1/5, 2/9, 3/13...$, $2/7, 3/11...$, $1/7....$ with odd denominator have been observed as are also $\nu = 1/2$ and $\nu = 5/2$ states with even denominator [D1].

The model of Laughlin [D13] cannot explain all aspects of FQHE. The best existing model proposed originally by Jain is based on composite fermions resulting as bound states of electron and even number of magnetic flux quanta [D9]. Electrons remain integer charged but due to the effective magnetic field electrons appear to have fractional charges. Composite fermion picture

predicts all the observed fractions and also their relative intensities and the order in which they appear as the quality of sample improves.

The generalization of the notion of embedding space suggests the possibility to interpret these states in terms of fractionized charge, spin, and electron number. There are four combinations of covering and factors spaces of CP_2 and three of them can lead to the increase of Planck constant. Besides this there are two options for the formula of Planck constant so that which the very meager theoretical background one can make only guesses. On the following just for fun consideration option I is considered although the conservation of number of states in the phase transition changing $\hbar$ favors option II.

1. The easiest manner to understand the observed fractions is by assuming that both M^4 and CP_2 correspond to covering spaces so that both spin and electric charge and fermion number are fractionized. This means that e in electronic charge density is replaced with fractional charge. Quantized magnetic flux is proportional to e and the question is whether also here fractional charge appears. Assume that this does not occur.

2. With this assumption the expression for the Planck constant becomes for Option II as $r = \hbar/\hbar_0 = n_a/n_b$ and charge and spin units are equal to $1/n_b$ and $1/n_a$ respectively. This gives $\nu = nn_a/n_b$. The values $m = 2, 3, 5, 7, ..$ are observed. Planck constant can have arbitrarily large values. There are general arguments stating that also spin is fractionized in FQHE.

3. The appearance of $\nu = 5/2$ has been observed [D7]. The fractionized charge is $e/4$ in this case. Since $n_i > 3$ holds true if coverings are correlates for Jones inclusions, this requires to $n_b = 4$ and $n_a = 10$. n_b predicting a correct fractionization of charge. The alternative option would be $n_b = 2$ that also Z_2 would appear as the fundamental group of the covering space. Filling fraction $1/2$ corresponds in the composite fermion model and also experimentally to the limit of zero magnetic field [D9]. $n_b = 2$ is however inconsistent with the observed fractionization of electric charge and with the vision inspired by Jones inclusions.

4. A possible problematic aspect of the TGD based model is the experimental absence of even values of n_b except $n_b = 2$ (Laughlin's model predicts only odd values of n). A possible explanation is that by some symmetry condition possibly related to fermionic statistics (as in Laughlin model) n_a/n_b must reduce to a rational with an odd denominator for $n_b > 2$. In other words, one has $n_a \propto 2^r$, where 2^r the largest power of 2 divisor of n_b.

5. Large values of n_a emerge as B increases. This can be understood from flux quantization. One has $e\int BdS = n\hbar(M^4) = nn_a\hbar_0$. By using actual fractional charge $e_F = e/n_b$ in the flux factor would give $e_F \int BdS = n(n_a/n_b)\hbar_0 = n\hbar$. The interpretation is that each of the n_a sheets contributes one unit to the flux for e. Note that the value of magnetic field in given sheet is not affected so that the build-up of multiple covering seems to keep magnetic field strength below critical value.

6. The understanding of the thermal stability is not trivial. The original FQHE was observed in 80 mK temperature corresponding roughly to a thermal energy of $T \sim 10^{-5}$ eV. For graphene the effect is observed at room temperature. Cyclotron energy for electron is (from $f_e = 6\times 10^5$ Hz at $B = .2$ Gauss) of order thermal energy at room temperature in a magnetic field varying in the range 1-10 Tesla. This raises the question why the original FQHE requires so low temperature. The magnetic energy of a flux tube of length L is by flux quantization roughly $e^2B^2S \sim E_c(e)m_eL$ ($\hbar_0 = c = 1$) and exceeds cyclotron roughly by a factor L/L_e, L_e electron Compton length so that thermal stability of magnetic flux quanta is not the explanation. A possible explanation is that since FQHE involves several values of Planck constant, it is quantum critical phenomenon and is characterized by a critical temperature. The differences of the energies associated with the phase with ordinary Planck constant and phases with different Planck constant would characterize the transition temperature.

As already noticed, it is possible to imagine several other options and the identification of charge unit is rather ad hoc. Therefore this model can be taken only as a warm-up exercise.

Chapter 5

The Notion of Wave-Genome and DNA as Topological Quantum Computer

5.1 Introduction

For about eight years ago - inspired by a representation in CASYS'2000 conference [I86] - I developed a model [K112, K17] for the fascinating effects of laser light on genome discovered by Peter Gariaev and his collaborators. This model is somewhat obsolete since it does not involve the recent TGD inspired vision about quantum biology and DNA, and the discussions with Peter in the second Unified Theories conference 2008 in Budapest made clear the need to update this model containing also some misinterpretations.

In this article the effects of laser light on living matter are discussed only briefly with a stronger emphasis on the photographs produced by the scattering of ordinary light on DNA reported in [I108]. In TGD framework these photographs could be interpreted as photographs of wormhole magnetic flux tubes containing dark matter. This would realize the dream of making directly visible the basic new structure predicted by TGD inspired quantum biology. Of course, a more conventional explanation might be found for the effect, but the proposed qualitative explanation deserves to be discussed since it fits nicely with the general vision about dark matter in TGD Universe.

5.1.1 The Findings Of Peter Gariaev And Collaborators

These findings of Gariaev and collaborators include the rotation of polarization plane of laser light by DNA [I86]. phantom DNA effect [I87]. the transformation of laser light to radio wave photons having biological effects [I89]. the coding of DNA sequences to the modulated polarization plane of laser light and the ability of this kind of light to induce gene expression in another organisms provided the modulated polarization pattern corresponds to an "address" characterizing the organism [I86]. and the formation of images of what is believed to be DNA sample itself and of the objects of environment by DNA sample in a cell irradiated by ordinary light in UV-IR range [I108].

Gariaev and collaborators have introduced the notion of wave genome [I86] requiring the coding of DNA sequences to temporal patterns of coherent em fields forming a bio-hologram representing geometric information about the organism. Code could mean that nucleotide is represented by a characteristic rotation angle for the polarization plane of linearly polarized laser radiation scattering from it. This kind rotation is known to be induced by chromosomes by a mechanism which to my best knowledge is poorly understood. Other open questions concern the precise identification of the substrate of the bio-hologram, of the reference wave and of information carrying wave, and of the mechanism making possible (quantum) coherence in macroscopic length scales.

The reading of the DNA sequence to a radiation pattern is assumed to rely on the propagation of an acoustic soliton along DNA [I86]. Whatever this process is, one should also identify the

reverse process inducing the activation of the genome as the target organism receives the radiation coding for the DNA provided the "address" is correct. One should also identify the mechanism transforming laser radiation to radio-waves at various frequencies as well as the mechanism creating what is believed to be the image of DNA sample and replicated images of some instruments used in experiment.

5.1.2 The Relevant Aspects Of TGD Based View About Living Matter

The called massless extremals (MEs or topological light rays) distinguish between TGD and Maxwell's electrodynamics: they represent classically signals propagating with light velocity in a precisely targeted and dispersion free way, and are therefore excellent candidates for the communication and control tools in the TGD based model for a living system as a conscious hologram [K68, K17, K35]. The notion of magnetic/field body, which can have layers of even astrophysical size, is an essential element of the model. Magnetic body uses biological body as a sensory receptor and motor instrument and MEs mediate sensory input and control signals between the two kinds of bodies [K35]. I have already earlier applied MEs and the notion of magnetic body in an attempt to understand Gariaev's findings [K17].

The new element is the model for DNA as topological quantum computer (TQC) [K3] based on time-like braidings of so called wormhole magnetic flux tubes connecting nucleotides to the lipids at lipid layers nuclear and cell membranes. The model leads to a wide variety of predictions about DNA itself [K3]. to a universal model for a tissue memory in terms of space-like braidings of wormhole magnetic flux tubes [K3]. to a more detailed model of nerve pulse explaining also the origin of EEG and its synchrony [K80]. to a model for the evolution of the genetic code [**?**]. to a model of catalyst action involving a phase transition reducing the value of Planck constant inducing the shortening of the flux tubes connecting the reacting molecules and thus forcing them to the vicinity of each other, and to a model of for protein folding [K5] in which the presence of wormhole magnetic flux tubes connecting bio-molecules becomes almost a definition for what it is to be living. It is interesting to combine these new ideas with the earlier [I86, I89] and more recent [I108] findings of Gariaev. Basically the challenge is to fuse the DNA as TQC model with the model of living systems as a conscious hologram [K17].

5.1.3 The Basic Assumptions Of Model Explaining Findings Of Gariaev

The basic assumptions of the model to be discussed are following.

1. The hierarchy of Planck constants requires a generalization of the notion of 8-D embedding space $H = M^4 \times CP_2$ obtained by gluing together almost copies of H like pages of book along common back. The pages of the book carry matter with various values of Planck constant and the particles at different pages of the book are dark relative to each other in the sense that they cannot appear in the same vertex of Feynman diagram. The particles at different pages of the book can however interact via classical fields and via the exchange of (for instance) photons which suffer a phase transition changing Planck constant as they leak between pages of the book. In principle it is therefore possible to photograph the magnetic flux tubes carrying dark matter, and the proposal is that this is what Gariaev and collaborators have actually achieved [I108].

2. Braid strands realized as wormhole magnetic tubes are identified as correlates for a directed attention. DNA connected by strands to (say) experimental instrument directs its attention to the instrument. One could perhaps say that DNA "sees" the surrounding world. Also ordinary attention for vision and other senses could involve flux tubes connecting DNA to the object of perception. This explains the ability of DNA to generate images of objects of external world [I108] . The hierarchy of Planck constants explains the transformation of laser light to radio waves [I89] as a phase transition increasing Planck constant and thus also wavelength but keeping the energy of photons as such.

3. Wormhole flux tubes carrying super-conducting matter in large $\hbar$ phase are characterized by anomalous em charges characterizing the nucleotides [K3]. and thus define an excellent candidate for the substrate of bio-hologram. A coding of DNA nucleotides to the rotation

of polarization plane results for photons traversing through these flux tubes if a large parity breaking making possible rotation of the polarization plane (Faraday effect) is assumed. This is possible by the large parity breaking of fractally scaled up variant of weak physics [K10] explaining also chiral selection.

4. The model for the nerve pulse [K80] leads to the model of EEG waves in which EEG rhythms induce a complete analog of reference waves whereas nerve pulse induces the analog of information carrying wave [K35]. The model predicts a fractal hierarchy of EEGs (EXGs) and their counterparts associated with long ranged color and electro-weak gauge fields having MEs as classical correlates. EEG rhythms are associated with propagating soliton sequences and nerve pulse corresponds to a propagating perturbation associated with this soliton sequence rather than soliton. The model predicts automatically the synchrony and spatiotemporal coherence of neural firing. EEG photons correspond to a large value of Planck constant implying that their energies are above thermal energy at physiological temperatures so that their effects on living matter are not masked by thermal noise.

   This model generalizes essentially as such to the recent context: the counterparts of nerve pulses propagate along the complex formed by DNA connected to the nuclear or cell membrane or even to another cell nucleus by flux tubes. The prediction is that gene expression can be coherent in the scale of organ and even that of population. This conforms with the notion of super-genome stating that the sequences of DNA strands in different nuclei organize along magnetic flux sheet like text lines at the page of a book. The notion of hyper-genome means that these books from different organisms in turn organize to a pages of a book at higher level of fractal hierarchy and give rise to a gene expression at the level of population or even biosphere.

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` [L19].

5.2 TGD Counterpart For Wave Genetics

The wave genetic model of Gariaev involves the assumption that soliton waves propagating along DNA induce the reading of DNA sequence to a pattern of radiation. DNA is known to rotate the polarization plane but it is unclear how the coding of DNA sequence to a rotation of polarization plane could be achieved.

Second key element is the notion of bio-hologram. It is assumed that fractality is somehow involved. The key questions are following.

1. What is the substrate of the bio-hologram assuming that it is not based on nonlinear action for electromagnetic field (four-wave mechanism)? The substrate should have size larger than wavelength so that chromosomes are too thin to act as substrate.

2. What guarantees coherence or even quantum coherence in macroscopic scales?

3. How reference wave and the wave carrying the information are represented?

5.2.1 The Notion Of Bio-Hologram In TGD Framework

TGD based model is based on the model of living matter inspired by the model of DNA as topological quantum computer [K3]. DNA is connected to other bio-molecules and also to lipid layers of nuclear and cell membrane by wormhole magnetic flux tubes providing a representation of the genetic code. Braids strands defined by the flux tubes make possible topological quantum computation with TQC programs coded by dynamical braidings of the flux tubes induced by the water flow near the vicinity of cell and nuclear membranes inducing the flow of the 2-D liquid crystal defined by the lipids of the membrane. Flux tubes are dynamical, being able to reconnect and in the case of wormhole flux tubes even disappear without breaking conservation of magnetic flux, and they serve as correlates for a directed attention at the molecular and perhaps even at higher levels. Dark matter at the flux tubes has a large value of Planck constant and therefore a slow

dissipation rate. Also superconductivity is possible and the predicted exotic nuclear physics allows bosonic chemical equivalents of all biologically important ions. Long range color and electro-weak interactions implying in particular large parity breaking are possible and could explain chirality selection in living matter.

It is easiest to introduce the model through questions and answers.

Q: What is the substrate of the bio-hologram and how coherence is obtained?

A: Magnetic flux tubes with large $\hbar$ define the substrate and make possible macroscopic quantum coherence. Visible photons can suffer a phase transition to large $\hbar$ variants with wavelengths scaled up like $\hbar$. The interpretation would be in terms of bio-photons and their dark variants [I99].

Q: How the Faraday effect results?

A: Flux tubes contain charged particles in super-conducting state so that diamagnetism results. Large parity breaking makes possible different propagation velocities for the two circular polarizations and thus Faraday effect resulting via the splitting of the linearly polarized wave to two circular polarizations fusing back again at the second end of the flux tube. The magnetic field along flux tubes induces Faraday rotation and codes DNA nucleotide to the rotation angle of the polarization plane.

Q: How coding is achieved?

A: Coding is achieved by the different total charges associated with flux tubes implying that the rotation angles for polarization plane depend on nucleotide. This would be made possible by anomalous em charge associated with DNA sheet of wormhole flux tube implying that the rotation of polarization plane is different for each nucleotide [K3].

Q: What is the identification of reference wave and for the wave representing the information?

A: The model for nerve pulse and EEG suggests that reference waves are induced as Josephson radiation from voltage waves propagating along DNA and represent a fractal variant of EEG. The voltages waves generating reference waves correspond to propagating soliton sequences for Sine-Gordon equation describing idealized cylindrical Josephson junction having as an analog series of coupled gravitational penduli. The propagating soliton sequence along DNA with constant phase differences between subsequent penduli would generate the reference wave as Josephson radiation. The analog of nerve pulse would result as one pendulum kicked so that it begins to oscillate instead of rotating and induces an propagating localized oscillation.

Microscopically cylindrical Josephson junction decomposes into junctions defined by the flux tubes and Josephson currents between the ends of the flux tubes generate em radiation as coherent photons. Josephson radiation would therefore give rise to bio-photons and their dark variants with same photon energy but scaled up wavelength. Obviously the transformation of laser photons to radio-wave photons can be understood in terms of this mechanism and the quantization of Planck constant implies quantization of the energies involved.

5.2.2 How To Fuse The Notion Of Bio-Hologram With The Model Of DNAs TQC?

In the most economical picture - inspired by what is known about ordinary computers - intronic sequences would represent the names for TQC programs constructed from basic modules and expressing their outcomes chemically. Calling of the name of TQC would activate the TQC. This would allow an extremely rich combinations of basic modules, explain why the intronic portion of DNA increases during evolution, and why organisms with essentially identical genomes can be at widely differing evolutionary levels (say humans and apes). A further nice feature is that the intronic DNA of a given organism can induce gene expression in an organism for which the genes involved are not identical so that mutations would not be fatal. The prediction is that addresses represented by introns and the portions of promoter regions representing the conjugates of these addresses should be highly conserved.

The reading of the name of TQC to a polarization modulation pattern of incoming light would generate a signal which initiates TQC program in another cell in the case that the reverse polarization to the same linear polarization along the entire length of receiving intronic piece - conjugate of the original - takes place. The resulting overall linear polarization should initiate TQC leading to the eventual gene expression. Why the condition that linear polarization is same along entire piece of the "name" is not quite clear.

Introns could be connected by flux tubes to a part of DNA initiating gene expression. One would expect that this portion of gene is conjugate of the intronic portion containing the name of submodule. This would make possible RAM type representation of TQC programs if the link to next activated part of genome is represented by this same mechanism: exactly similar mechanism realizes links electromagnetically in web. A nucleus performing TQC infects large number of nuclei to perform the same TQC. Same could occur even at the level of population since very large values of $\hbar$ are possible.

5.3 The Effects Of Laser Light On Living Matter

The effects of laser light on living matter are discussed in the following briefly from TGD point of view.

5.3.1 Phantom DNA Effect

In phantom DNA effect [I87] there is an elastic scattering of the coherent laser radiation from irradiated DNA. When one removes the DNA from the chamber containing it, and irradiates it by laser light, a weak pattern of scattered light is still produced as if there were a kind of phantom DNA there. The pattern can last for months.

For years ago I considered an explanation of the effect based on dropping of part of DNA to larger space-time sheets characterized by larger value of p-adic prime and remaining in the vessel as visible DNA is removed [K112, K17]. A variant of this explanation inspired by the dark matter hierarchy is that the anomalous scattering takes place on dark DNA at wormhole flux tubes remaining in the vessel.

The most science fictive possibility is that the flux tubes connect the vessel boundaries to the removed DNA by wormhole flux tubes which are very long and correspond to a large value of $\hbar$. In this case the scattering would involve a phase transition increasing the value of Planck constant and a travel of photons to the removed DNA and back followed by a phase transition to ordinary photons.

Similar explanation works also in the case of homeopathy and allows to understand why the classic experiments of Benveniste [I82, I83] could not be replicated when experimenters did not know which bottles contained the treated water [K47]. In this case the molecules dissolved in water would lose their magnetic bodies as a consequence of the shaking of the homeopathic remedy and one can say that clusters of water molecules would steal their magnetic coats. This would allow them to mimic the behavior of molecules and their presence would allow the immune system would develop a resistance against real molecules. This of course works only if the cyclotron radiation from the magnetic body is responsible for the biological effects. It is known that em radiation at low frequencies is indeed responsible for the ability of molecules to recognize each other. The generation of cyclotron radiation requires metabolic energy and the magnetic flux tubes connecting the experimenter to the treated bottle of water (correlates for directed attention) could have served as bridges along which metabolic energy could be transferred by using topological light rays (MEs serving as TGD counterparts of Alfven waves). Experimentalists certainly did have strong desire to have successful experiments and this helped to realize the transfer of the metabolic energy.

5.3.2 Effects Of The Polarization Modulated Laser Light On Living Matter

Polarized light with a suitable temporal pattern for the modulation of polarization direction induces biological effects. The effects are not caused to arbitrary target and one can say that the part of target genome involved has an address characterized by a temporal pattern of polarization

modulation resulting in the propagation of the scaled variant of nerve pulse along chromosome. DNA is known to induce a rotation of polarization plane of incoming linearly polarized light and Gariaev suggests that the address is due to the propagation of a soliton along DNA inducing the modulation [I86].

TGD based model for the rotation of the polarization plane is based on Faraday effect [K9].

1. Usually diamagnetic dielectric causes the Faraday effect. The effect is due to different propagation velocities of left and right circular polarizations and recombination of polarizations to linear polarization. The rotation of the polarization plane would be caused by a Faraday effect at flux tubes. Superconductivity would imply ideal diamagnetism. Dielectric property is probably not present but large parity breaking due to long range weak interactions [K10] could explain why circular polarizations propagate with different velocities. Strong parity breaking could be caused by the presence of electro-weak gauge fields behaving like massless fields below the cell length scale and would explain also chiral selection. For large values of $\hbar$ the range of these fields would be scaled up accordingly.

2. The travel of the photon along a transversal flux tube starting from DNA nucleotide induces a rotation of the direction of polarization plane. The reverse rotation of polarization plane takes place as the light propagates in the reverse direction. The reverse propagation restoring the original overall linear polarization is expected to induce the biological along the portion of DNA in question. Phase conjugate light might be also involved.

3. The coding of DNA sequences to radiation patterns results since the charge Q associated with the nucleotide end of the wormhole magnetic flux tube affects Faraday rotation and is different for each nucleotide. The value of the charge is given by $Q = -2+Q_a$, where -2 units come from phosphate and Q_a corresponds to the charge of the quark (u, d) or antiquark ($\overline{u}$, $\overline{d}$) at the DNA space-time sheet associated with wormhole magnetic flux tube formed by a pair of space-time sheets connected by wormhole contacts having at its light-like throats quark and antiquark [K3]. Hence the rotation of the polarization plane depends on the nucleotide.

5.3.3 Plr Spectroscopy

Bio-systems could generate holograms in much more concrete sense than the wetty and hot and noisy character of this environment would suggest: even mechanisms generating laser beams could be there. The findings of Peter Gariaev and collaborators described in the article "The spectroscopy of bio-photons in non-local genetic regulation" [I89] led to a concrete model for how bio-photons affect many-sheeted DNA, and in this manner induce a generation of coherent radio waves and ELF waves [K17]. The recent picture brings in the hierarchy of Planck constants and suggests a modification of this model.

The effect

In polarizing laser-radio wave spectroscopy (PLR-spectroscopy) laser light scatters from the target substance. In the experiments of Gariaev *et al* red light ($\lambda = 632.8$ nm, 1.9595 eV) generated by He-Ne laser is used. This energy actually corresponds very precisely to one of the fundamental metabolic energy quanta identified as liberated zero point kinetic energy of proton as it drops from certain space-time sheet to much larger space-time sheet. There are two orthogonal polarizations correlated in intensity in such a way that the total intensity remains constant. After the interaction of one mode with the target substance, the reflected light is returned to the optical resonator, where the re-distribution of the intensity of these modes occurs. One of the laser modes, at a certain mode of generation, is able during the interaction with the target substance to induce polarization modulated radio waves of a wide spectrum correlated with the modulations of the optical modes of the laser radiation. The modulation is assumed to relate to rotational fluctuations of micro-structural components (say, domains of crystals) and of their optical activity. The PLR-spectrum is present also for in-organic materials. For biological targets there is spectral memory effect present, which means that the radio wave radiation continues even when the laser beam is not present anymore.

The frequency interval of the radio emission settles down at the 1 MHz. The PLR-spectrum is depicted in figures 1 and 2 of [I89] for apofillit crystal. The frequency spectrum for the radio waves has a modulated fractal structure suggesting that spectrum is superposition of spectra which consist of harmonics $n_1 f_h - n_2 f_l$ of higher frequency f_h modulated by harmonics of scaled down frequency $f_l = x f_h$. Almost identical copies of a piece of length about

$$\Delta f \sim 100\ Hz$$

appear in a sequence as the pictures 1 and 2 of [I89] for the spectrum of apofillit crystal in 1560-1860 Hz range demonstrate. This suggests the presence of harmonics of basic frequencies perhaps shifted by a constant amount. Cyclotron and spin flip transitions in magnetic field suggest itself.

There is also gross structure consisting of peaks in scale of kHz suggesting harmonics of frequency of order kHz. For wheat seed (picture 3 of [I89]) the strongly expressed frequency ranges are identified as 800-900 Hz (to my personal opinion the band is 300-900 Hz), 1700-1900 Hz, 2400-2600 Hz, 3600-3800 Hz (to my personal opinion a wider frequency range 1700-2200 Hz is strongly expressed). There is also strongly expressed frequency band below 300 Hz. Also the spectrum of high polymerization DNA sample from calf thymus (picture 4 of [I89]) shows a clear peak at 2400-2600 Hz and less pronounced peaks at lower frequencies.

The radio wave radiation from DNA samples is accompanied by specific effects on bio-systems such as ab-normally fast germination and re-vitalization of seeds. Thus it seems that the radio wave radiation is able to restore the genetic control apparatus and the vitality of the seeds.

TGD based explanation of the effect

Dark matter hierarchy suggests the interpretation of radio-wave photons as large $\hbar$ photons with energy equal to that of the original photon. Biophotons and their dark variants could form Bose-Einstein condensates at the wormhole magnetic flux tubes. The flux tubes associated with DNA would transform laser photons to radio wave photons by inducing $\hbar$ increasing phase transition. Large value of $\hbar$ would increase the range of interactions so that they would become possible even in the scale of biosphere. In particular, coherent gene expression in the scale of organism and even population. Genetic code could be represented as radiation patterns with the charges assignable to the end of DNA space-time sheet of flux tube providing the coding.

5.4 The Scattering Of Incoherent UV-IR Light On DNA

The proposed model for the findings about scattering of incoherent UV-IR light from DNA lead to an amazing conclusion that the experiments make directly visible the magnetic flux tubes containing dark matter.

5.4.1 Basic Facts

The figures of the article [I108] give valuable information about what is involved. There are two experimental arrangements.

1. In the first experiment dry/dehydrated DNA is contained in a small seal containing a conical cylinder (4 cm long, .9 cm at its upper end) or 3 ml of DNA water solution 1 mg/ml. The radiation by UV-C lamp lasts for 10 minutes: note that UV-C wavelengths are in the range 280-10 nm.

2. In the second experiment the DNA sample is in open cell and a light source known as Duna-M irradiates red light from 21 LEDS (650 nm) and IR light (920 nm) from 16 LEDs. Also UV-B lamp and Compact electronic CEST26E17 Black lamp are involvedUV-B wavelengths are in the range 315-280 nm. The light sources are turned on and off with intervals of 2-3 seconds. The exposure time is 1 second.

   The basic findings are following [I108].

1. The effects occur only if the sample contains DNA.

2. A large number (tens) of closely spaced replica images of nearby objects, in particular the red LED. The replicas for the image of instrument are along strictly horizontal half line (see **Fig.** 1).

3. The replica sequences of the instruments appear periodically suggesting that the energy of incoming photons is gradually accumulated and liberated in a burst. The interference by an external DNA source (touching by finger of DNA cell) changes the direction of the half line which disappears at the next exposure to white light.

4. Single vertical curved band like image of roughly the same height as the entire image and with more or less the same width as the distance between replicas of the instrument parts appears to the left from the instrument image (see **Fig. 10.2**). This image is not replicated in the horizontal direction. The fine structure of the band for one of the reported images (see **Fig. 10.3**) however suggests that also the band like structure consists of replicas of same size as the replicas associated with instruments. The band like structure for second method decomposes to 5 red parallel curves (see **Fig. 10.4**) for which the interpretation as images of 5 red LEDs is proposed based on the observation that these LEDs irradiate directly the DNA cell. The phantom of DNA image remains intact for some time after the irradiation.

If I have understood correctly, the interpretation proposed in [I108] is following.

1. The sequence of the horizontal images of the instrument would result from a motion of single image moving during the exposures: this requires that the motion is fast in the time scale of exposure. The appearance of equally spaced replicas forces to assume that the motion occurs in discrete jumps in horizontal direction.

2. The band like structure is identified as the image of DNA sample. The band is assumed to correspond to a discrete and non-predictable motion of single image.

There are objections against the idea that the motion of single image produces the image. In particular, the discreteness of the motion looks strange. One can also wonder why the motion for the image of the instrument is strictly horizontal whereas the motion of DNA image is not horizontal and is curvilinear. One can also ask whether the an image of DNA sample is actually in question since the position of the band like structure is to left from the cell containing the DNA.

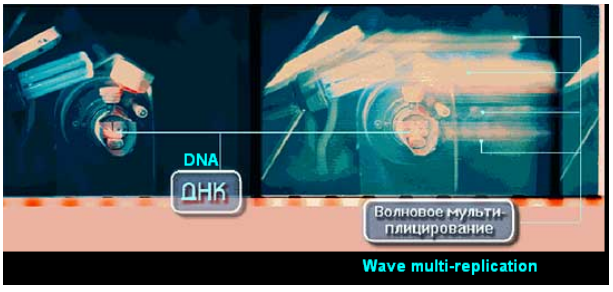

Figure 5.1: The left hand side figure is from [I108] and represents the replica images of the instruments and the image interpreted by experimenters as a replica image of DNA sample (second method).

5.4.2 TGD Based Model For The Replicas

One can consider two models for the replicas. The first model assumes that the images are images of dark magnetic flux tubes. Second model assumes that in the case of instrument images diffraction is involved.

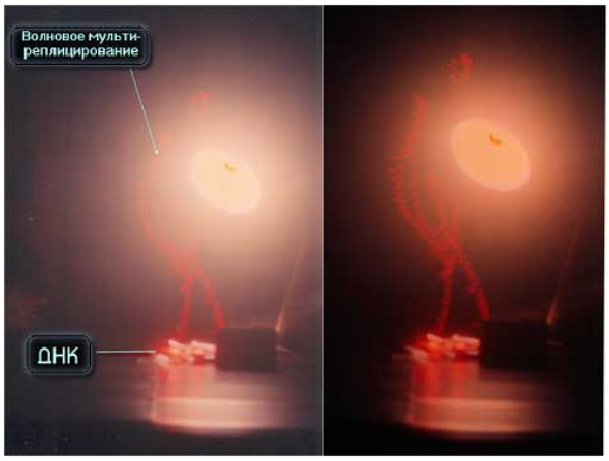

Figure 5.2: The picture shows the discrete replica like structure of the band like image interpreted by experimenters as replica image of DNA sample (first method).

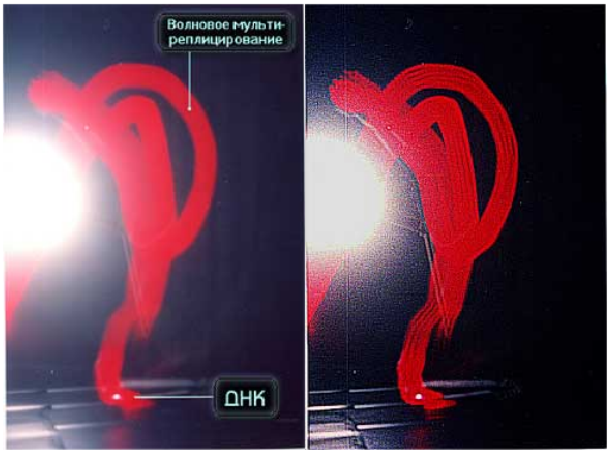

Figure 5.3: The picture reveals the 5-fold fine structure of the band like image interpreted by experimenters as replica image of DNA sample. The 5-fold character probably correspond to five red LEDs above the sample (second method).

Have wormhole magnetic magnetic flux tubes containing dark matter been photographed?

The most elegant model for the effects found hitherto relies on the assumption that both the horizontal replica sequences and the band like structures having also replica structure correspond to real structures, most naturally (wormhole) magnetic flux tubes. In the case of instrument replicas they would emanate directly from the instruments. In the case of DNA image they would emanate from a position to the left from the cell containing DNA. The presence of DNA should somehow generate the flux tubes.

1. In the case of horizontal replications of instruments the replicas would be associated with a magnetic flux tube emanating horizontally from the instruments to the right. Replicas would be obtained if a dipole distribution assignable to the surface of object and representable in terms of Fourier transform restricted to a box containing the object and having discrete momentum spectrum is extended to a periodic Fourier transform along the horizontal flux

tube. Flux tube would thus represent a series of images of the geometric object and this would make possible to communicate the data through long distances.

2. Also the DNA image could be the image of a curved flux tube assignable to the cell containing the DNA. The band like structure does not however begin from the cell containing DNA being located left from it. A possible explanation is that there topological light ray connecting the cell containing DNA to a similar sized cell at the end of the flux tube irradiating it with photons emitted from the dipole distribution at its surface. The resulting induced dipole distribution representable in terms of a discrete Fourier transform is then continued along the entire curved flux tube and would generate the replicas.

3. The replication of the dipole distribution along the entire length of the flux tube requires macroscopic quantum coherence suggesting a large value of Planck constant. If the coherence is required at least in the length scale L of the flux tube, one obtains ratio $r = \hbar/\hbar_0 \geq L/\lambda \simeq 10^6$ for $L = .5$m and $\lambda = 500$ nm. This value could correspond to the favored value $r = 2^{20}$ and thus to a favored value of Planck constant [K38]. A weaker condition is obtained by replacing L with the size a of the cell giving $r \geq a/\lambda \simeq 2 \times 10^5$ for $a = .1$ m.

4. If the flux tubes correspond to large value of Planck constant, the dark photons emanating from them must transform to ordinary photons since diffractive effects are not involved.

5. The fact that the images of the flux tubes appear periodically suggests that a Bose-Einstein condensate of dark photons is gradually formed at them which bursts out as some critical number of dark photons are present and leaks to the visible sector of the 8-D embedding space becoming ordinary photons. One can visualize the sectors of the generalized 8-D embedding space as pages of a book characterized by different values of Planck constant so that the leakage would occur from page to another one through the back of the book.

6. The effect of touching in the second type experiment involving LEDs can be understood if the touching reverses the direction of the magnetic flux tubes assigned with the instruments. The disappearance of the replicated instrument image 5-8 seconds after the touching could relate to the instability of the right-oriented flux tubes. If the right-directed flux tube is mirror image of the left oriented flux tube, the instability might relate to a parity breaking possible in TGD Universe by the presence of scaled variants of weak interactions. The preferred orientation of the flux tube might be also determined by something in environment, say resources of metabolic energy. If the flux tubes are correlates for attention, one can even imagine that DNA with the mediation of flux tubes directs its attention to something interesting.

There are also some open questions.

1. Why the flux tube assignable to the DNA is curved and why the image of this flux tube does not emanate from the sample?

2. How the presence of DNA induces the generation of the flux tubes? The model for DNA as TQC would suggest that the thin wormhole magnetic flux tubes connecting DNA to the instruments induce the effect, and that the flux tubes explaining the image correspond to higher level structures with larger value of Planck constant and are somehow induced by the presence of DNA. They could also correspond to a larger value of p-adic prime but same value of Planck constant. Perhaps one might say that the magnetic body of DNA makes the instruments in some sense part of its biological body by directing its attention to them.

3. Why the touching chances the orientation of the flux tube?

If this model is on a right track, the findings would mean a direct observation of dark magnetic flux tubes by the em radiation of dark photons transformed to ordinary photons as they leak out from dark sectors of the embedding space to the sector containing the matter visible to us.

The explanation in terms of diffraction does not work

For the sake of completeness also the interpretation of the replication of the images of the instrument and DNA cell in terms of diffraction is discussed although this explanation forces several ad hoc assumptions unlike the previous model.

1. The appearance of the replicas along horizontal half-line $x > 0$ brings strongly in mind a diffraction through a vertical slit defined by a vertical dark flux sheet attached to the instrument and acting as a window. This requires coherence so that ordinary visible light cannot be responsible for the image whereas dark photons with a large enough value of Planck constant makes the quantum coherence possible.

2. The amplitude for a diffraction through slit behaves as $A = sin(x)/x$, $x = \pi \times (a/\lambda) \times sin(\theta)$, where θ is the angle between the normal of the slit and direction of observation. Hence the maxima of the intensity maxima correspond to the central maximum $\sin(\theta) = 0$ given by geometric optics and $\sin(\theta) = (n+1/2) \times \lambda/a$ so that for small angles one has $\Delta\theta = \lambda/a$ and the distance between replicas is $x = d\Delta\theta = d\lambda/a$.

3. The distance between the replicas in the image requires a wavelength longer than used in experiments. Thus dark photons with a scaled up wavelength $\lambda = r\lambda_0$, $r = \hbar/\hbar_0$, transforming by Planck constant changing phase transition to ordinary photons in camera could be in question. The value of the Planck constant can be deduced by using the geometric data, the values of wavelength, and the distance between the replicas of instrument images assuming that diffraction effectively takes place through a vertical slit with width of order size of typical replicated instrument, say seal. From $\theta \leq D/d$, where D is the size of camera aperture, and from the number n of horizontal replicas $n < 100$ one obtains the estimate $d\lambda/a \sim D/nd$. This gives $\lambda/a \sim D/nd^2$. For $D = .01$ m, $d = .5$ m, one would have $\lambda/a \sim 4 \times 10^{-4}$. For $\lambda = 4 \times 10^{-7}$ m this would give $a \sim 10^{-3}$ m. The appearance of details in the replicated image suggest that a is of the same order than the instrument size so that one has $a \geq x > 1$ cm giving $\hbar/\hbar_0 \geq 10x$. The value of λ seems to be too small to allow coherence in the required length scale.

4. The serious problem of this interpretation is that the diffraction pattern for a diffraction through slit corresponds to maxima at an entire transversal line rather than half-line. It is as if the effective vertical flux sheet attached to the left hand side of the object would contain a distribution of horizontal dipoles generating radiation interfering to zero at the left half of the half-space. This distribution should be determined by the radiation coming from the object so that a kind of induced emission process would be in question. One can also imagine is that the dark space-time sheet along which photons arrive is half-space with horizontal coordinate $x \geq 0$. What is intriguing that in p-adic physics for which the values of variables finite in real sense are always positive as real numbers so that half-lines, quadrants, octants, ... are very natural objects. One must admit that this assumption looks ad hoc.

5. There is also a second problem. The evidence for the replication of same basic unit with the size of the DNA containing cell suggests that a replication of the image of cell containing the DNA along a curved band is in question with essentially the same distance between replicas as in the previous case. It is impossible to have a curved slit producing this kind of diffraction pattern. One could consider also the possibility that the band corresponds to a real structure, may be magnetic flux tube, and that Planck constant is now larger than in the case of instrument images so that only the central image of the diffraction pattern is visible in the camera. This however forces to ask whether also the replicas of instruments correspond to magnetic flux tubes so that one would end up with the first model.

5.5 Water Memory, Phantom DNA Effect, And Development Of TQC Hardware

This section describes speculative picture in which a connection between homeopathy and water memory [K47] with phantom DNA effect is proposed and on basis of this connection a vision

about how the TQC hardware represented by the genome is actively developed by subjecting it to evolutionary pressures represented by a virtual world representation of the physical environment.

5.5.1 A Possible Realization Of Water Memory

The Benveniste's discovery of water memory [I82, I83] initiated quite dramatic sequence of events. The original experiment involved the homeopathic treatment of water by human antigene. This meant dilution of the water solution of antigene so that the concentration of antigene became extremely low. In accordance with homeopathic teachings human basophils reacted on this solution.

The discovery was published in Nature and due to the strong polemic raised by the publication of the article, it was decided to test the experimental arrangement. The experimental results were reproduced under the original conditions. Then it was discovered that experimenters knew which bottles contained the treated water. The modified experiment in which experimenters did not possess this information failed to reproduce the results and the conclusion was regarded as obvious and Benveniste lost his laboratory among other things. Obviously any model of the effect taking it as a real effect rather than an astonishingly simplistic attempt of top scientists to cheat should explain also this finding.

The model based on the notion of field body and general mechanism of long term memory allows to explain both the memory of water and why it failed under the conditions described.

1. Also molecules have magnetic field bodies acting as intentional agents controlling the molecules. Nano-motors do not only look co-operating living creatures but are such. The field body of the molecule contains besides the static magnetic and electric parts also dynamical parts characterized by frequencies and temporal patterns of fields. To be precise, one must speak both field and relative field bodies characterizing interactions of molecules. Right brain sings-left brain talks metaphor might generalize to all scales meaning that representations based on both frequencies and temporal pulse with single frequency could be utilized.

2. The effects of complex bio-molecule to other bio-molecules (say antigene on basofil) in water could be characterized to some degree by the temporal patterns associated with the dynamical part of its field body and bio-molecules could recognize each other via these patterns. This would mean that symbolic level in interactions would be present already in the interactions of bio-molecules. Cyclotron frequencies are most natural candidates for the frequency signatures and the fact that frequencies in 10 kHz range are involved supports this view.

3. The original idea was that water molecule clusters are able to mimic the bio-molecules themselves -say their vibrational and rotational spectra could coincide with those of molecules in reasonable approximation. A more natural idea is that they can mimic their field bodies. Homeopathy could rely on extremely simple effect: water molecule clusters would steal the magnetic bodies of the molecules used to manufacture the homeopathic remedy. The shaking of the bottle containing the solution would enhance the probability for bio-molecule to lose its magnetic body in this manner. For instance, water could produce fake copies of say antigenes recognized by basofils and reacting accordingly if the reaction is based on interaction with the magnetic body of the antigene.

4. The basic objection against this picture is that it does not explain why the repeated dilution works. Rather, it seems that dilution of molecules reduces also the density of mimicking pseudo-molecules. Even more, the potency of the homeopathic remedy is claimed to increase as the dilution factor increases. Also alcohol is used instead of water so that also alcohol must allow homeopathic mechanism. (I am grateful for Ulla Matfolk for questions which made me to realize these objections).

   (a) The only way out seems to be that the magnetic bodies or water molecule clusters having these magnetic bodies can replicate. The shaking of the remedy could provide the needed metabolic energy so that the population of magnetic bodies grows to a limiting density determined by the metabolic energy feed. In principle it would be possible to infect unlimited amount of water by these pseudo-molecules. When in bottle the population would be in dormant state but in the body of the patient it would wake up and form

a population of molecular actors and stimulate the immune system to develop immune response to the real molecule.

(b) The potency of the homeopathic remedy is claimed to increase with the increased dilution factor. This would suggest that the continued dilution and shaking also increases the density of pseudo molecules, perhaps by feeding to the system metabolic energy or by some other mechanism.

(c) Also magnetic bodies must replicate in cell replication and their role as intentional agents controlling bio-matter requires that this replication serves as a template for biochemical replication. On can indeed interpret the images about cell replication in terms of replication of dipole type magnetic field. This process is very simple and could have preceded biological replication. The question is therefore whether water is actually a living system in presence of a proper metabolic energy feed. Also the water's ability near critical point for freezing to form nice patterns correlating with sound stimuli might be due to the presence of the molecular actors.

(d) This picture fits nicely with the vision that evolution of water in this kind of life form might have happened separately and that pre-biotic chemical life forms have formed symbiosis with living water [**?**]. In the model of DNA as topological quantum computer [K3] the asymptotic self organization patterns of water flow in the vicinity of lipid layers indeed define quantum computer programs by inducing the braiding of the magnetic flux tubes connecting DNA nucleotides to lipids so that this symbiosis would have brought in new kind of information processing tool.

5. The magnetic body of the molecule could mimic the vibrational and rotational spectra using harmonics of cyclotron frequencies. Cyclotron transitions could produce dark photons, whose ordinary counterparts resulting in de-coherence would have large energies due to the large value of $\hbar$ and could thus induce vibrational and rotational transitions. This would provide a mechanism by which molecular magnetic body could control the molecule. Note that also the antigenes possibly dropped to the larger space-time sheets could produce the effect on basofils.

6. There is a considerable experimental support for the Benveniste's discovery that bio-molecules in water environment are represented by frequency patterns, and several laboratories are replicating the experiments of Benveniste as I learned from the lecture of Yolene Thomas in the 7: th European SSE Meeting held in Röros [J18]. The scale of the frequencies involved is around 10 kHz and as such does not correspond to any natural molecular frequencies. Cyclotron frequencies associated with electrons or dark ions accompanying these macromolecules would be a natural identification if one accepts the notion of molecular magnetic body. For ions the magnetic fields involved would have a magnitude of order.03 Tesla if 10 kHz corresponds to scaled up alpha band. Also Josephson frequencies would be involved if one believes that EEG has fractally scaled up variants in molecular length scales.

Consider now the argument explaining the failure to replicate the experiments of Benveniste.

1. The magnetic bodies of water molecules need metabolic energy for communications with their "biological body" using the fractally scaled analog of EEG. There is no obvious source for this energy in water. The model for protein folding and DNA as topological quantum computer assumes that magnetic flux tubes connecting subject person and target of directed attention serve as correlates for directed attention at the molecular level [K3, K5]. This should be true also in macroscopic scales so that the experimentalist and the bottle containing the treated water should be connected by magnetic flux tubes. If experimenter has directed his attention to the bottle of water, the resulting magnetic flux tubes could allow a transfer of metabolic energy as a radiation along massless extremals parallel to the flux tubes and defining TGD counterparts of Alfven waves. Experimenter's strong motivation to replicate experiments would help to realize the transfer of the metabolic energy. Experimenters not knowing, which bottles were treated did not have these flux tube bridges to the bottles, and were not able to provide the needed metabolic energy, and the magnetic bodies of antigenes failed to generate the cyclotron radiation making them visible to the basofil.

2. If this interpretation is correct, then Benveniste's experiment would demonstrate besides water memory also psychokinesis and direct action of desires of experimenters on physics at microscopic level. Furthermore, the mere fact that we know something about some object or direct attention to it would mean a concrete interaction of our magnetic body with the object. The so called phenomenon of psi track [J39] provides additional support for this conclusion.

5.5.2 Could Virtual DNAs Allow A Controlled Development Of The Genome?

The fundamental question in the evolution biology is the question about the interaction between genome (G), phenotype (P), and environment (E).

1. The standard dogma is that the information transfer from G to P is unidirectional and that environment acts on G by inducing random mutations of G, from which E selects the lucky survivors as those with the best ability to reproduce. Lamarckism [I18, I72, I84] represents a deviation from standard dogma by assuming direct information transfer from E to G.

2. Genetic expression is controlled by environment, at least by silencing [I18], which is like selecting only few books to be read from a big library. Cell differentiation represents basic example of selective gene expression. DNA methylation and transposition are accepted to reflect information transfer from E to G, perhaps via P. These modifications are believed to be short lasting and not transferred to the offspring since it is difficult to imagine a mechanism transferring the mutations to the germ cells. There is however also evidence that epigenetic information transfer takes place [I121]: this transfer would be selective expression of genes of germ cells rather than that of modified genes.

3. There are findings challenging the dogmas of static genome and random mutations. The cells of the immune system remodel their genes coding for antibodies capable of recognizing large variety of antigens. There is quite recent finding [I92] revealing major genetic differences between blood and tissue cells. There are also mutations due to jumping genes - mobile elements of DNA known as LINE-1 elements usually regarded as junk DNA whose portion from genome increases as one climbs up along the evolutionary ladder. In mice jumping genes are limited to brain and germ cells: this is easy to understand since in organs like heart and lungs this kind of mutations would be fatal. Second recent discovery is that there is a high diversity of human brain cells believed to be due to the jumping genes [I68]. That brain cells would be producing with a high rate junk DNA is not an idea which would make me shout "Eureka!"

4. The question however remains whether the $G \to P - E$ actually could complete to a closed loop $G \to P - E - G$ so that genome could directly respond to the changing physical environment and could transfer the successful response to the next generation [I72].

Could genome be developed like computer hardware?

In TGD framework the sequence $G \to P - E$ is replaced with a closed loop $G - P - M - E$ to which E is attached at P by bidirectional arrow (organisms do also modify their environment actively). Magnetic body thus controls genome and receives information from cell membrane (P). The hierarchy of genomes (super-genome, hyper-genome, ...) corresponding to the different levels of dark matter hierarchy allows this loop to be realized in different scales rather only at the level of single cell.

The question is whether the magnetic body of organism or higher level magnetic bodies could modify genomes, super-genomes, and hyper-genomes directly, perhaps by generating mutations of the genome in a short time scale; by monitoring how genetically modified organism survives in the environment; and -if the outcome of the experiment is successful - replacing the corresponding portion of DNA with the modified DNA both in ordinary germ cells. One can even ask whether the abstract model of the external environment provided by the internal chemical milieu might be mimicked by water magnetic bodies of water molecule clusters and provide a virtual world testing ground for a search of favorable mutations.

In DNA as a TQC vision essentially the development of a new computer hardware would be in question, and should take place in a controlled manner and involve an experimentation before going to the market rather than by random modifications taking place in computer CPUs. Second basic aspect of DNA as TQC paradigm is that water and bio-molecules live in symbiosis in the sense that self organization patterns of the cellular water flow define the TQC programs. The following first guess for how the development of computer hardware might be achieved is just a first guess but might have something to do with reality.

1. What would be needed is a mechanism generating rapidly modifications of DNA. The mutations should be carried out using a kind of virtual DNA mimicking all the essential aspects of the symbolic dynamics associated with DNA. The magnetic bodies of DNA consisting of flux tubes connecting the nucleotides of DNA strands to cell membrane satisfy these conditions since A, T, G, C is coded to exotic light quarks u, d and anti-quarks $\overline{u}$, $\overline{d}$ at the ends of flux tubes [K3]. DNA nucleotides could be replaced with clusters of water molecules but also other options can be imagined. Note that it does not matter when one speaks of mimicry of RNA or DNA molecules.

2. If the proposed model of the phantom DNA and homeopathy has something to do with reality, this kind of virtual DNA exists and is generated in phantom DNA effect as magnetic bodies of DNA, including of course the magnetic flux tubes connecting the nucleotides to the cell membrane or conjugate strand of DNA.

3. The crucial additional assumption would be that also the reversal of phantom DNA effect is possible and corresponds to the analog of DNA replication in which nucleotides attach to the virtual conjugate nucleotides of the virtual DNA strand or RNA strand in turn transformed to DNA strand be reverse transcription. The hypothesis would have rather strong implications for the genetic engineering since homeopathic remedies of genetically engineered DNA sequences could be transferred to cell nuclei just by drinking them.

4. Phantom DNA sequences could form populations and - as far as their properties as a hardware of topological quantum computer are involved - evolve under selection pressures of the virtual world defined by the nuclear, cellular and extracellular water. A competition of components of TQC hardware developed by the higher level magnetic body to realize optimally TQC programs needed for survival would be in question. The simplest mutation of phantom DNA would replace the quark pairs at the ends the (wormhole-) magnetic flux tube with a new one and could occur in very short time scale. Also basic editing operations like cutting and pasting would be possible for these competing phantom DNA sequences. The winners in the competition would be transformed to actual DNA sequences by utilizing the reverse phantom DNA (or RNA -) effect and be inserted to genome. The genetic machinery performing cutting, gluing, and pasting of real DNA in a controlled manner exists. What is needed is the machinery monitoring who is the winner and making the decision to initiate the modification of the real DNA.

5. The transfer of the mutations to germ cells could be achieved by allowing the population of the virtual DNA sequences to infect the water inside germ cells. The genetic program inducing the modification of DNA by using the winner of the TQC hardware competition should run automatically.

6. One open question is whether the nuclear, cellular or perhaps also extracellular water should represent the physical environment and - if answer is affirmative - how it achieves this. As a matter fact, considerable fraction of water inside cells is in gel phase and it might be that the intercellular water, which naturally defines a symbolic representation of environment, is where the virtual evolution takes place. Internal chemical milieu certainly reflects in an abstract manner the physical environment and the ability of the water molecule clusters to mimic bio-molecules would make the representation of the chemical environment possible. Also sudden changes of external milieu would be rapidly coded to the changes in internal milieu which might help to achieve genetic re-organization. The craziest dream is water based simulation of both genes, proteins, and molecules representing external world running at dark space-time sheets.

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

The minimal option is that virtual DNA sequences have flux tube connections to the lipids of the cell membrane so that their quality as hardware of TQC can be tested but that there is no virtual variant of transcription and translation machinery. One can however ask whether also virtual amino-acids could be present and whether this could provide deeper insights to the genetic code.

1. Water molecule clusters are not the only candidates for the representatives of linear molecules. An alternative candidate for the virtual variants of linear bio-molecules are dark nuclei consisting of strings of scaled up dark variants of neutral baryons bound together by color bonds having the size scale of atom, which I have introduced in the model of cold fusion and plasma electrolysis both taking place in water environment [L2], [L2]. Colored flux tubes defining braidings would generalize this picture by allowing transversal color magnetic flux tube connections between these strings.

2. This seems to work! The states of dark nucleons formed from three quarks can be naturally grouped to multiplets in one-one correspondence with 64 DNAs, 64 RNAS, and 20 amino-acids and there is natural mapping of DNA and RNA type states to amino-acid type states such that the numbers of DNAs/RNAs mapped to given amino-acid are same as for the vertebrate genetic code.

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

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

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

   (a) Baryonic strings could form a helical nuclear string (stability might require this) locally parallel to DNA, RNA, or amino-acid) helix with rotations acting either along the axis of the DNA or along the local axis of DNA along helix. The rotation of a flux tube portion around an axis parallel to the local axis along DNA helix requires that magnetic flux tube has a kink in this portion. An interesting question is whether this kink has correlate at the level of DNA too. Notice that color bonds appear in two scales corresponding to these two strings. The model of DNA as topological quantum computer [K3] allows a modification in which dark nuclear string of this kind is parallel to DNA and each codon has a flux tube connection to the lipid of cell membrane or possibly to some other bio-molecule.

   (b) The analogs of DNA -, RNA -, and of amino-acid sequences could also correspond to sequences of dark baryons in which baryons would be 3-quark strings in the plane transversal to the dark nuclear string and expected to rotate by stringy boundary conditions. In this case all dark baryons would be free to rotate. Thus one would have nuclear string consisting of short baryonic strings not connected along their ends.

2. The new element as compared to the standard quark model is that between both dark quarks and dark baryons can be charged carrying charge $0, \pm 1$. This is assumed also in nuclear string model and there is empirical support for the existence of exotic nuclei containing charged color bonds between nuclei.

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

$$\sum_q Q_{em}(q) = -\sum_{flux\ tubes} Q_{em}(flux\ tube) \ . \tag{5.5.1}$$

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

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

1. States in the quark degrees of freedom

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

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

1. The tensor product $2 \otimes 2 \otimes 2$ is involved in both cases. Without any additional constraints this tensor product decomposes as $(3 \oplus 1) \otimes 2 = 4 \oplus 2 \oplus 2$: 8 states altogether. This is what one should have for DNA and RNA candidates. If one has only identical quarks *uuu* or *ddd*, Pauli exclusion rule allows only the 4-D spin 3/2 representation corresponding to completely symmetric representation -just as in standard quark model. These 4 states correspond to a candidate for amino-acids. Thus RNA and DNA should correspond to states of type uud and ddu and amino-acids to states of type *uuu* or ddd. What this means physically will be considered later.

2. Due to spin-statistics constraint only the representations with $(J, I) = (3/2, 3/2)$ (Δ resonance) and the second $(J, I) = (1/2, 1/2)$ (proton and neutron) are realized as free baryons. Now of course a dark -possibly p-adically scaled up - variant of QCD is considered so that more general baryonic states are possible. By the way, the spin statistics problem which forced to introduce quark color strongly suggests that the construction of the codons as sequences of 3 nucleons - which one might also consider - is not a good idea.

3. Second nucleon like spin doublet - call it 2_{odd} - has wrong parity in the sense that it would require $L = 1$ ground state for two identical quarks (*uu* or *dd* pair). Dropping 2_{odd} and using only $4 \oplus 2$ for the rotation group would give degeneracies $(1,2,2,1)$ and 6 states only. All the representations in $4 \oplus 2 \oplus 2_{odd}$ are needed to get 8 states with a given quark charge and one should transform the wrong parity doublet to positive parity doublet somehow. Since open string geometry breaks rotational symmetry to a subgroup SO(2) of rotations acting along the direction of the string and since the boundary conditions on baryonic strings force their ends to rotate with light velocity, the attractive possibility is to add a baryonic stringy excitation with angular momentum projection $L_z = -1$ to the wrong parity doublet so that

the parity comes out correctly. $L_z = -1$ orbital angular momentum for the relative motion of uu or dd quark pair in the open 3-quark string would be in question. The degeneracies for spin projection value $J_z = 3/2, ..., -3/2$ are $(1, 2, 3, 2)$. Genetic code means spin projection mapping the states in $4 \oplus 2 \oplus 2_{odd}$ to 4.

2. States in the flux tube degrees of freedom

Consider next the states in flux tube degrees of freedom.

1. The situation is analogous to a construction of mesons from quarks and antiquarks and one obtains the analogs of π meson (pion) with spin 0 and ρ meson with spin 1 since spin statistics forces $J = I$ condition also now. States of a given charge for a flux tube correspond to the tensor product $2 \otimes 2 = 3 \oplus 1$ for the rotation group.

2. Without any further constraints the tensor product $3 \otimes 3 = 5 \oplus 3 \oplus 1$ for the flux tubes states gives 8+1 states. By dropping the scalar state this gives 8 states required by DNA and RNA analogs. The degeneracies of the states for DNA/RNA type realization with a given spin projection for $5 \oplus 3$ are $(1, 2, 2, 2, 1)$. $8\times$ 8 states result altogether for both uud and udd for which color bonds have different charges. Also for ddd state with quark charge -1 one obtains $5 \oplus 3$ states giving 40 states altogether.

3. If the charges of the color bonds are identical as the are for uuu type states serving as candidates for the counterparts of amino-acids bosonic statistics allows only 5 states ($J = 2$ state). Hence 20 counterparts of amino-acids are obtained for uuu. Genetic code means the projection of the states of $5 \oplus 3$ to those of 5 with the same spin projection and same total charge.

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

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

1. The analogs of DNA and RNA can be identified dark baryons with quark content uud, ddu with color bonds having different charges. There are 3 color bond pairs corresponding to charge pairs $(q_1, q_2) = (-1, 0), (-1, 1), (0, 1)$ (the order of charges does not matter). The condition that the total charge of dark baryon vanishes allows for uud only the bond pair $(-1, 0)$ and for udd only the pair $(-1, 1)$. These thus only single neutral dark baryon of type uud *resp.* udd: these would be the analogous of DNA and RNA codons. Amino-acids would correspond to uuu states with identical color bonds with charges $(-1, -1)$, $(0, 0)$, or $(1, 1)$. uuu with color bond charges (-1, -1) is the only neutral state. Hence only the analogs of DNA, RNA, and amino-acids are obtained, which is rather remarkable result.

2. The basic transcription and translation machinery could be realized as processes in which the analog of DNA can replicate, and can be transcribed to the analog of mRNA in turn translated to the analogs of amino-acids. In terms of flux tube connections the realization of genetic code, transcription, and translation, would mean that only dark baryons with same total quark spin and same total color bond spin can be connected by flux tubes. Charges are of course identical since they vanish.

3. Genetic code maps of $(4 \oplus 2 \oplus 2) \otimes (5 \oplus 3)$ to the states of 4×5. The most natural map takes the states with a given spin to a state with the same spin so that the code is unique. This would give the degeneracies $D(k)$ as products of numbers $D_B \in \{1, 2, 3, 2\}$ and $D_b \in \{1, 2, 2, 2, 1\}$: $D = D_B \times D_b$. Only the observed degeneracies $D = 1, 2, 3, 4, 6$ are predicted. The numbers $N(k)$ of amino-acids coded by D codons would be

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

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

doublet. If 2 codons in 4-plet become stopping codons it also becomes doublet and one obtains the correct result $(2, 9, 1, 5, 3)$!

4. Stopping codons would most naturally correspond to the codons, which involve the $L_z = -1$ relative rotational excitation of *uu* or *dd* type quark pair. For the 3-plet the two candidates for the stopping codon state are $|1/2, -1/2\rangle \otimes \{|2, k\rangle\}$, $k = 2, -2$. The total spins are $J_z = 3/2$ and $J_z = -7/2$. The three candidates for the 4-plet from which two states are thrown out are $|1/2, -3/2\rangle \otimes \{|2, k\rangle, |1, k\rangle\}$, $k = 1, 0, -1$. The total spins are now $J_z = -1/2, -3/2, -5/2$. One guess is that the states with smallest value of J_z are dropped which would mean that $J_z = -7/2$ states in 3-plet and $J_z = -5/2$ states 4-plet become stopping codons.

5. One can ask why just vertebrate code? Why not vertebrate mitochondrial code, which has unbroken $A - G$ and $T - C$ symmetries with respect to the third nucleotide. And is it possible to understand the rarely occurring variants of the genetic code in this framework? One explanation is that the baryonic realization is the fundamental one and biochemical realization has gradually evolved from non-faithful realization to a faithful one as kind of emulation of dark nuclear physics. Also the role of tRNA in the realization of the code is crucial and could explain the fact that the code can be context sensitive for some codons.

4. Understanding the symmetries of the code

Quantum entanglement between quarks and color flux tubes would be essential for the baryonic realization of the genetic code whereas chemical realization could be said to be classical. Quantal aspect means that one cannot decompose to codon to letters anymore. This raises questions concerning the symmetries of the code.

1. What is the counterpart for the conjugation $ZYZ \to X_c Y_c Z_c$ for the codons?

2. The conjugation of the second nucleotide Y having chemical interpretation in terms of hydrophobia-hydrophily dichotomy in biology. In DNA as TQC model it corresponds to matter-antimatter conjugation for quarks associated with flux tubes connecting DNA nucleotides to the lipids of the cell membrane. What is the interpretation in now?

3. The A-G, T-C symmetries with respect to the third nucleotide Z allow an interpretation as weak isospin symmetry in DNA as TQC model. Can one identify counterpart of this symmetry when the decomposition into individual nucleotides does not make sense?

Natural candidates for the building blocks of the analogs of these symmetries are the change of the sign of the spin direction for quarks and for flux tubes.

1. For quarks the spin projections are always non-vanishing so that the map has no fixed points. For flux tube spin the states of spin $S_z = 0$ are fixed points. The change of the sign of quark spin projection must therefore be present for both $XYZ \to X_c Y_c Z_c$ and $Y \to Y_c$ but also something else might be needed. Note that without the symmetry breaking $(1, 3, 3, 1) \to (1, 2, 3, 2)$ the code table would be symmetric in the permutation of 2 first and 2 last columns of the code table induced by both full conjugation and conjugation of Y.

2. The analogs of the approximate $A - G$ and $T - C$ symmetries cannot involve the change of spin direction in neither quark nor flux tube sector. These symmetries act inside the A-G and T-C sub-2-columns of the 4-columns defining the rows of the code table. Hence this symmetry must permute the states of same spin inside 5 and 3 for flux tubes and 4 and 2 for quarks but leave 2_{odd} invariant. This guarantees that for the two non-degenerate codons coding for only single amino-acid and one of the codons inside triplet the action is trivial. Hence the baryonic analog of the approximate $A - G$ and $T - C$ symmetry would be exact symmetry and be due to the basic definition of the genetic code as a mapping states of same flux tube spin and quark spin to single representative state. The existence of full 4-columns coding for the same amino-acid would be due to the fact that states with same quark spin inside $(2, 3, 2)$ code for the same amino-acid.

3. A detailed comparison of the code table with the code table in spin representation should allow to fix their correspondence uniquely apart from permutations of n-plets and thus also the representation of the conjugations. What is clear that Y conjugation must involve the change of quark spin direction whereas Z conjugation which maps typically 2-plets to each other must involve the permutation of states with same J_z for the flux tubes. It is not quite clear what X conjugation correspond to.

5. Some comments about the physics behind the code

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

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

2. Both the absolute and relative mass differences between Δ and N *resp.* ρ and π are large in ordinary hadron physics and this makes the decays of Δ and ρ possible kinematically. This is due to color magnetic spin-spin splitting proportional to the color coupling strength $\alpha_s \sim .1$, which is large. In the recent case α_s could be considerably smaller - say of the same order of magnitude as fine structure constant 1/137 - so that the mass splittings could be so small as to make decays impossible.

3. Dark hadrons could have lower mass scale than the ordinary ones if scaled up variants of quarks in p-adic sense are in question. Note that the model for cold fusion that inspired the idea about genetic code requires that dark nuclear strings have the same mass scale as ordinary baryons. In any case, the most general option inspired by the vision about hierarchy of conscious entities extended to a hierarchy of life forms is that several dark and p-adic scaled up variants of baryons realizing genetic code are possible.

4. The heaviest objection relates to the addition of $L_z = -1$ excitation to $S_z = |1/2, \pm 1/2\rangle_{odd}$ states which transforms the degeneracies of the quark spin states from $(1, 3, 3, 1)$ to $(1, 2, 3, 2)$. The only reasonable answer is that the breaking of the full rotation symmetry reduces $SO(3)$ to $SO(2)$. Also the fact that the states of massless particles are labeled by the representation of $SO(2)$ might be of some relevance. The deeper level explanation in TGD framework might be as follows. The generalized embedding space is constructed by gluing almost copies of the 8-D embedding space with different Planck constants together along a 4-D subspace like pages of book along a common back. The construction involves symmetry breaking in both rotational and color degrees of freedom to Cartan sub-group and the interpretation is as a geometric representation for the selection of the quantization axis. Quantum TGD is indeed meant to be a geometrization of the entire quantum physics as a physics of the classical spinor fields in the "world of classical worlds" so that also the choice of measurement axis must have a geometric description.

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

Crying and screaming cells and magnetic bodies expressing their emotions

By using nanotechnological methods James Gimzewski [J1], his student Andrew Pelling and collaborators discovered that the cell walls of bacterium Saccharomyces cerevisiae perform periodic motion with amplitude about 3 nm in the frequency range.8-1.6 kHz (one octave) [I98]. Or more

concretely, bacteria produce sounds audible to humans with average frequency of 1 kHz in a range of one octave. The frequency has strong temperature dependence, which suggests a metabolic mechanism. From the temperature dependence one deduces the activation energy to be 58 kJ/mol, which is consistent with the cell's metabolism involving molecular motors such as kinesin, dynein, and myosin. The magnitude of the forces observed (10 nN) suggests concerted nanomechanical activity is operative in the cell.

From less formal popular articles [I73] one can learn that it is difficult to avoid the impression that intelligent communication is in question. Dying cells produce a characteristic screaming sound. One can also distinguish between normal cells and cancel cells on basis of the sound they produces as well as between mammalian and bacterial cells.

What might be the explanation of these findings in TGD framework?

1. It is known that the region of frequencies audible to human ear is from about 20 Hz to 2×10^4 Hz. This is more or less same as the range of frequency range of sferics, the em noise in atmosphere [F1]. This suggests a strong coupling between electromagnetic oscillations and sound as also the fact that biological structures are piezo-electrets transforming em oscillations to sounds and vice versa.

2. The activation energy per mole corresponds to.6 eV per molecule which is at the upper range for the variation range the energy associated with the fundamental metabolic energy quantum identified as the change of zero point kinetic as proton is transferred from atomic space-time sheet to much larger space-time sheet or vice versa.That metabolic energy is needed to produce the sounds supports the view that the sounds are produced intentionally.

3. If one takes seriously the notion of magnetic body as intentional agent controlling biological body, one is led to ask which must sound a totally crazy question in reductionistic ears: could magnetic body express its emotions in terms of frequencies of cyclotron transitions transformed to sound via genetic expression using piezo electric mechanism? Could it be that the photons involved are dark photons with large value of Planck constant so that their energy is above thermal energy. Could one propose a materialistic scientist to consider anything more irritating that singing and crying magnetic bodies!

4. Suppose that the homeopathic mechanism is based on replication of pseudo-molecules with same magnetic body as that of solvent molecules and that neutral dark nuclear strings realize analogs of DNA, RNA, and amino-acids and realizing genetic code exactly in its vertebrate nuclear form and appearing also in the TGD based model of cold fusion and biological transmutations. If so, then homeopathic mechanism (recognition of molecules) could involve also the transformation of cyclotron radiation to sound at the level of "biological bodies" of molecules.

5. If this picture makes sense then also our speech as a self expression of the magnetic body might involve genetic code mapping sequences of DNA codons to temporal patterns of cyclotron radiation in turn transformed to speech by above mechanism. This would require a realization of genetic code at level of dark matter: could it be that dark nuclear code could define universal quantum level realization of language? The findings of Peter Gariaev and others and structural resemblance of intronic portion of genome with language and their report that DNA sequences are coded to temporal patterns of the rotation angle of the polarization of laser light (in turn inducing genetic expression).

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Chapter 6

Quantum Gravitation and Topological Quantum Computation

6.1 Introduction

In this article the connection of quantum gravitation, as it is understood in the TGD framework, with topological quantum computation (TQC) is considered. I sketched the first TGD based vision about DNA as a TQCer for about 13 years ago. In particular, a model of the system consisting of DNA and nuclear/cell membrane system acting as a TQCer was discussed [K4, K3, K106].

TGD has evolved a lot after this and there are several motivations for seeing what comes out from combining the recent view about quantum TGD and TGD inspired quantum biology with this model.

1. There is a rather detailed view about the role of dark matter as phases of ordinary matter with the effective Planck constant $h_{eff} = nh_0$. Large values of h_{eff} allow to overcome the problems due to the loss of quantum coherence.

   This leads to the notion of the dark DNA (DDNA), whose codons are realized as dark proton triplets and proposed to accompany the ordinary DNA [L28, L88]. Also dark photon triplets are predicted [L20] [L60, L68] and one ends up to a model of communications and control based on dark cyclotron resonance in which codons serve as addresses and modulation of the signal frequency scale codes the signal to a sequence of pulses. Nerve pulses could be one application.

2. Quite recently, also the understanding of the possible role of quantum gravitation in bio-chemistry, metabolism, bio-catalysis, and in the function of DNA [L81] has considerably increased. The gravitational variants of hydrogen bonds and valence bonds between metal ions having very large value of $h_{eff} = h_{gr}$, where $h_{gr} = GMm/v_0$ is the gravitational Planck constant [L42] [K89, K69, K72] originally introduced by Nottale [E1], are in a key role in the model and explain metabolic energy quantum as gravitational energy liberated when dark protons "drops" from a very long gravitational flux tube in the transition $h_{gr} \to h$. Also electronic metabolic energy quantum is predicted and there is empirical support for this.

3. A further motivation comes from the number theoretic vision of quantum TGD. Galois groups as symmetry groups represent new physics [L67, L65, L66] and the natural questions are whether Galois groups could give rise to number theoretic variants of anyons and what could the TGD counterparts of the condensed matter (effective) Majorana electrons proposed by Kitaev [D18] as anyon like states?

   The answer is that quantum superpositions of symmetric hydrogen bonded structures of form X..H-H+X-H...X are excellent candidates for the seats of dark ($h_{eff} > nh_0 > h$) bi-localized electrons defining TGD analogs of condensed matter Majorana electrons.

The Galois groups permute the roots of a polynomial, which determines a space-time region by $M^8 - H$ duality. The roots correspond to mass squared values, in general algebraic numbers, and thus to mass hyperboloids in $M_c^4 \subset M_c^8$. The H images correspond to 3-hyperboloids with a constant value of light-cone proper time. Therefore the Galois group permutes points with time-like separation.

This looks very strange at first but actually confirms with the fact that time-like braidings defining TQC correspond in TGD time-like braidings (involving also reconnections) of string like objects defining string world sheets, which are not now time evolutions of space-like entities as physical state but correspond to time-like entities defining boundary data necessary for fixing holography completely. Their presence is forced by the small failure of the determinism of the action principle involved and is completely analogous to the non-determinism for soap films with frames serving as seats for the failure of determinism.

4. Braidings appear therefore at the level of fundamental TGD and correspond to string world sheets. They are possible only in 4-D space-time but not in string models.

   Also TQC-like processes appear automatically at the level of fundamental physics. In particular, the number theoretical state function reduction cascade for the Galois group [L62] following the time evolution induced by braiding can be regarded as a generalization of a decomposition of integers to primes: now primes are replaced by simple groups defining primes for finite groups. Nature is doing number theory!

5. Also zero energy ontology (ZEO) [L56, L71] brings in new elements. The change of the arrow of time in "big" state function reductions (BSFRs) implies that dissipation with a reversed arrow of time provides an automatic error correction procedure. Also TQC in which the arrow of time varies for sub-modules, can be considered.

6.1.1 Two visions about physics in TGD framework

TGD leads to two visions about physics discussed in [L61, L74]. In the first vision [K49, K27, K86] physics is seen as geometry of space-time identified as 4-surface in $H = M^4 \times CP_2$, and at a more abstract level, geometry of the "world of classical worlds" (WCW) consisting of space of preferred extremals (PEs) of the basic action principle defining analogs of Bohr orbits as minimal surfaces with singularities.

In the second vision [K96] physics is reduced to number theoretic concepts and 4-surfaces in M^8 analogous to momentum space define the basic objects. $M^8 - H$ duality [L57, L58], analogous to momentum-position duality, relates the two visions. The 4-surfaces in M_c^8 (complexified M^8), which has interpretation as complexified octonions, are required to be associative in the sense that their normal space is quaternionic.

For given space-time region, they are determined by the roots of polynomial P of real argument continued to polynomials in M_c^8. The roots define a collection of mass shells of $M_c^4 \subset M_c^8$ and by holography they define a 4-D surface of H.

The action principle at the level of H is determined by the twistor lift of TGD and is the sum of 4-D Kähler action and volume term (cosmological constant). It is not fully deterministic and space-time surfaces in H as PEs analogous to Bohr orbits can be regarded as analogs of soap films with frames, which correspond to singularities at which determinism fails.

The frames provide additional holographic data besides the hyperbolic 3-surfaces corresponding to light-bone proper times $a = a_n$ which are determined by the roots of P. Frames include light-like orbits of partonic 2-surfaces and string world sheets connecting them. What is new, and consistent with zero energy ontology (ZEO) [K113], is that space-like data are not enough for holography, also time-like data is required and the string world sheets turn out to be absolutely essential for braiding and TQC.

Physics as geometry

The basic elements of physics as geometry are following.

1. Space-time is identified as minimal 4-surface [L75] in $H = M^4 \times CP_2$. Holography follows from general coordinate invariance and implies what might be called Bohr orbitology. It turns out that holography is not quite strict.

2. Twistor lift of TGD [L39] [L76, L77] replaces space-time surface with what can be regarded as a counterpart of its twistor space having X^4 as a base space and sphere CP_1 as a fiber. The twistor structure is induced from the product of $T(M^4) \times T(CP_2)$ of twistor spaces $T(M^4)$ $TC(P_2)$, which are the only twistor spaces allowing Kähler structure. The induced twistor structure and determined by an action principle with is 6-D Kähler action existing only for M^4 and CP_2. Twistor structure requires dimensional reduction so that one bundle structure and the action reduces to a sum of a volume term having interpretation in terms of cosmological constant and of 4-D Kähler action as analog of Maxwell action.

   PEs realizing the holography are identified as minimal surfaces [L75], which, apart for lower-dimensional singularities, are also locally extremals of the 4-D Kähler action and possess a holomorphic structure reducing the field equations to algebraic conditions analogous to Cauchy-Riemann conditions. One can regard the space-time surface as an analog of soap film spanned by frames assignable to the singularities at which minimal surface property fails but extremal property for the entire action remains true so that conservation laws are not lost. As in the case of ordinary soap films, frames are seats of finite non-determinism interpreted as space-time correlates of quantum non-determinism.

3. The concrete study of the extremals of the action principle leads to the identification of the basic candidates for the basic PEs. From the point of view of TQC, magnetic flux tubes are the most interesting objects and define counterparts of the braid strands. The notion of magnetic body (MB) is central. Its detailed identification is still far from complete: for the latest view about gravitational MB see [L81].

Physics as a generalized number theory and $M^8 - H$ duality

Physics as (a generalized) number theory is the dual vision of TGD.

1. p-Adic physics emerged originally from a model for the particle massivation based on p-adic thermodynamics for the mass squared of the particle [K57, K24]. From the beginning it was clear that various p-adic physics had to be fused with the real number based physics to a larger framework, which could be called adelic physics. For mathematical reasons, the natural interpretation of various p-adic physics would be in terms of physical and mathematical correlates of cognition. Number theoretical universality stating that the basic equations of TGD are number-theoretically universal and make sense in all number fields is a natural constraint on the theory.

2. $M^8 - H$ duality [L57, L58] realizes the number theoretical vision about TGD and also holography. M^8_c identified as complexified M^8 and interpreted as complexified octonions, is analogous to momentum space and 4-surfaces define the basic objects at the level of M^8.

   The 4-surfaces in M^8_c (complexified M^8), which have an interpretation as complexified octonions, are required to be associative in the sense that their normal space is quaternionic. These 4-surfaces are determined by the roots of polynomials of real argument continued to polynomials in M^8_c. The roots define a collection of 3-D mass shells of $M^4_c \subset M^8_c$ and by holography they define a 4-D surface of M^8_c. Physical states correspond to 4-momenta at these mass shells analogous to Fermi balls.

   $M^8 - H$ duality, analogous to momentum-position duality, relates the two visions by mapping the 4-surfaces in M^8 to those in H. $M^8 - H$ duality generalizes to the level of twistor space [L57, L58, L74, L76, L77].

3. One can assign to a given polynomial an algebraic extension of rationals. The collection of points of the 4-surface of M^8_c defines a cognitive representation. The mass shells as sources of holographic data are however number theoretically exceptional in that the number of points with algebraic M^8_c coordinates is infinite: cognitive explosion takes place both at the level of

M^8 and H: these values of the light-one proper time a correspond to very special moments in the life of self, kind of moments of enlightenment.

In M^8 the points of mass shells are identifiable as quark momenta assumed to be algebraic integers just as ordinary momenta for particles in a box are integers with suitable choice of momentum unit. These momenta can also be interpreted as points in extension of p-adic numbers so that number theoretical universality follows. The p-adic prime in question is identified as the largest ramified prime of the extension considered.

This gives rise to a hierarchy of algebraic extensions and cognitive representations as unique discretizations of the 4-surface in M^8 and space-time surface and suggests a generalization of computationalism replacing integers with the hierarchy of algebraic integers for extensions of rationals.

4. The dimension n of algebraic extension is identified as an effective Planck constant $h_{eff} = nh_0$ where $h_0 < h$ is true. The identification of the value of n_0 in $h = n_0 h_0$ has been proposed [L70]. The phases of ordinary matter labelled by the value of n behave in many respects as dark matter and the identification as dark matter has been proposed. A particularly important class of phases corresponds to $h_{eff} = nh_0$. These phases would play a central role in living matter. The relationship with galactic dark matter is however somewhat unclear.

   What makes these phases so important is the scale of quantum coherence is expected to scale like h_{eff}. Dark phases are also expected to have very weak interaction with ordinary matter and the proposal is that living matter is controlled by this kind of phases located at MB and approaching only slowly thermal equilibrium with it: this would have interpretation as aging [L101]. The small value of h and thermal fluctuations spoiling quantum coherence and entanglement belong to the key problems of QC and dark matter could solve these problems.

5. Galois confinement [L65] states that physical states have total momenta, whose components are ordinary integers. Galois confinement provides a universal mechanism for the formation of bound states. Galois confinement also applies in spin degrees of freedom and provides spin representations for the covering of the Galois group. The number theoretic degrees of freedom are of special interest in QC and suggest that number theoretic quantum computation (NQC) as a counterpart of TQC, which would involve what might be called Galois anyons. The Galois group could allow identification as a subgroup of the braid group. This would mean strong restrictions on TQC.

6. $M^8 - H$ duality leads to a view about the construction of the counterpart of S-matrix in the TGD framework [L76, L77]. S-matrix would be replaced by the analog of Kähler metric in fermionic degrees of freedom [L64], which by the infinite dimension of Fock space is expected to be highly unique as also the Kähler metric of WCW [K49, K27, K86].

   Incoming and outgoing states of particle scattering would be Galois singlets constructed from lower level states which need not be Galois singlets. Quarks, whose momenta at mass shells are algebraic integers are free and the scattering would be mere reorganization of Galois singlets to new ones.

   Scattering could be also seen as analog of QC and computation in an extension of rationals: both the input and output would consist of a set of rational integer valued momenta and scattering would map them to each other.

   This applies in the twistor picture also to spins having a representation as points of the twistor sphere S^2 known as Bloch sphere. In this case number theoretic constraints suggest that the set of quantization axes corresponds to a finite discrete subgroup of $SO3$) assignable to regular polygons and Platonic solids.

   The quark momenta belonging to the extensions of rationals are invisible, which implies invisible algebraic complexity of cognition and brings in mind unconscious information processing. Quantum physics and psychoanalysis would meet!

6.1.2 Zero energy ontology (ZEO) and QC

The first basic motivation for the introduction of ZEO was that by the general coordinate invariance space-time surface as a preferred extremal is a more natural notion than 3-surface. For exact

holography, these notions are equivalent but the identification of space-time surface as minimal surface predicts a small violation of the strict holography identifiable as a correlate for quantum non-determinism associated with the physics of cognition or possibly quite generally. This non-determinism would be essential for the possibility of TQC in TGD.

Second motivation was the basic problem of quantum measurement theory to which ZEO provides an elegant solution if one assumes that the arrow of time changes in "big" state functions reductions (BSFRs) as analogs of ordinary SFRs. In "small" SFRs, which are analogs of "weak" measurements introduced in quantum optics, the arrow is not changed [K113] [L56, L71].

In the TGD framework, quantum measurement theory generalizes to a quantum theory of conscious experience in which SSFR defines the basic element of conscious experience. BSFR has an interpretation as a counterpart of death/sleep. The change of the arrow of time in BSFRs has profound implications in quantum biology. Since the dissipation with a reversed arrow of time for a subsystem looks like self-organization from the point of view of a system with an opposite arrow of time [L55]. The arrow of time can change for macroscopic time periods at the MBs with large h_{eff} and since MB controls the ordinary matter, it induces not only effective quantum coherence but also an effective reversal of time also at this level.

The basic ideas of ZEO [L56, L71] are following.

1. In zero energy ontology (ZEO) [L56, L71], the pair of incoming and outgoing states of particle scattering are replaced with zero energy state and zero energy states define scattering amplitudes as entanglement coefficients.

2. At the level of H, positive and negative energy parts of zero energy states are located at boundaries of causal diamonds (CD), which form a fractal hierarchy. At the level of M^8, they reside at the boundaries of mass shells, which corresponds to the roots of the polynomial defining the space-time region. $M^8 - H$ duality maps these points to the boundary of CD. One can also consider an alternative for which mass shells as hyperbolic spaces $H^3 \subset M^8$ are mapped to their counterparts in H by a map which is essentially inversion (Uncertainty Principle).

3. Scattering events [L76, L77] are QC like events. Input (output) data correspond to incoming (outgoing) quark momenta identified as algebraic integers in an extension of rationals and to spins. Since fermionic Fock state basis defines a Boolean algebra, the fermionic states define quantum analog of Boolean algebra, and the scattering amplitudes could be also seen as a quantum generalization of Boolean maps and realizing statements which are true that is consistent with laws of physics. These transitions could be interpreted in terms of Boolean cognition.

   The replacement of the S-matrix with Kähler metric in fermionic Hilbert space degrees of freedom represents a new element. The analog of unitary transformation is assigned with CD and from the point of view of QC, CD could be interpreted as an embedding space analog of gate. Since gates allow control bits not affected by the unitary transformation, also the Boolean functions, which are not 1-1, can be realized as unitaries. Same is expected to be true also now.

4. The scattering amplitudes correspond a tensor net-like structure. Physical states are Galois singlets consisting basically of free quarks. At the number theoretical level, scattering can be seen as a recombination of Galois singlets to new ones.

ZEO could have a profound impact on QC.

1. Negentropy Maximization Principle (NMP) [K60] [L69] is the variational principle of TGD inspired theory of consciousness. Negentropy can correspond to the sum of p-adic negentropies or to the sum or p-adic and real negentropies, which can be possible and tends to be so by NMP. For both options, NMP guarantees that the p-adic entanglement negentropy increases and is positive. It however also forces the real entanglement entropy to grow. NMP therefore implies cognitive evolution but also second law.

   From the point of view of QC, this picture is very promising since the laws of physics would take care that the entanglement negentropy grows and also that negentropic entanglement

tends to be stable. This is quite contrary to what standard physics predicts. This leads to evolution [L36, L37] in the sense that the dimension $n = h_{eff}/h_0$ of the extension of rationals as a measure of algebraic complexity tends to increase since this provides larger negentropic resources. This evolution takes place at MB in human length and time scales and the challenge is to learn to manipulate dark matter.

2. BSFR could take care of error correction automatically since for the reversed arrow of time dissipation looks like error correction by self-organization. This error correction is a key feature of living matter but has remained poorly understood. One can also ask whether BSFRs could make possible QCs involving sub-QCs in both time directions. Could the use of sub-programs with opposite time direction allow a faster QC.

6.1.3 Finite field approximation and QC

Number theoretic vision about QC leads to new ideas about QC itself.

1. The momenta in the extension of rationals as algebraic integers can be interpreted as p-adic integers in the induced extension of p-adic numbers. The p-adic number field corresponds to prime p, which is the maximal ramified prime for the polynomial in quesetion.

   In the approximation $O(p) = 0$ they define a finite field $F(p, n)$ having dimension is is not larger than the dimension of extension but can be smaller. The number of elements is p^n and the situation corresponds to n pinary digits, qupits, instead of qubits. TQC using elements of $F(p, n)$ is an attractive possibility. Besides this one has also spin degrees of freedom.

2. The elements of $F(p, n)$ can be regarded as roots of some, in general non-unique, polynomial with degree p^n. This polynomial is in general not the polynomial inducing the extension of p-adic numbers.

3. The Galois group for the finite field should transform to each other the roots of the originalpolynomial interpreted as a polynomial in $F(p, n)$ and is a subgroup of the Galois group for the polynomial having all points of $F(p, n)$ as its roots.

The automorphism group of quaternions is analogous to Galois group and in the TGD framework with discretization it looks like a natural notion.

1. In the continuous case, the automorphism group of quaternions is the rotation group $SO(3)$ having $SU(2)$ as covering group. In the discrete situation, one expects it to be a finite group and would correspond to symmetries of Platonic solid in non-abelian case and to the symmetries of a regular polygon in abelian ase. Icosahedron, tetrahedron, and octahedron have triangles as faces and the proposal is that genetic code realized in terms of bioharmony [L20] [L60] corresponds to so called icosa-tetrahedral tessellation of H^3 [L68].

2. Therefore genetic code and bioharmony could closely relate to the quaternionic aspects of number theoretic physics and perhaps also to TQC for quantum variant $SU(2)_q$ of quaternionic automorphisms acting in the normal space of the space-time surface. A natural proposal is that the points of the icosahedron and tetrahedron correspond to points for the discretized unit sphere known as Bloch sphere defining possible directions of the quantization axis of spin in TQC.

3. The finite subgroups of $SU(2)$ are associated with the hierarchy of inclusions of hyperfinite factors of type II_1 and the proposal is that the inclusion of these factors define finite measurement resolution such that the included factor defines the resolution [K110, K39].

6.1.4 TQC and the new view about space-time

The new view about space-time is highly relevant for the TGD view of TQC.

Galois anyons

The basic problem of the TGD inspired model of TQC is the identification of the topological qubit identified as an anyon-like state in standard TQC. One could say that topological qubit or its analog does not correspond to quantum state but representation of braid group or quantum group assignable to Chern-Simons action. Topological qubits also satisfy a nice algebra defined by the decomposition rules of the representations of the braid group.

The motivation for this identification is that topological qubits are expected to be highly stable since the change of the representation is not expected to be probable unlike the change of spin direction. The non-local character is also an important aspect. The braids defining TQC program as unitary representation of the braid group allows to identify the gates, which are universal in the sense that they have finite computational accuracy.

The increase of the order of the covering group as a finite covering of the permutation group S_N for N braid strands allows to improve the accuracy. Kitaev [B8, B7] has proposed [D18] that anyon-like bi-localized states of condensed matter Majorana fermions could define stable qubits. Majorana electrons would be superpositions of electron states localized at the ends of a superconducting wire and would have parity $+/-1$ under permutations of ends of the wire.

In TGD framework the electrons defining analogs could be bi-localized states with localization to the ends of a monopole flux tube or pair of them. Galois degrees of freedom are a new element and anyons could correspond to multi-localized states defining representations of Galois group at its orbits consisting of points of the cognitive representation at mass shell H^3. Also spin degrees of freedom would define Galois representation. If the braidings correspond to lifts of number theoretic symmetries, Galois group corresponds to a subgroup of the braid group.

In the standard picture of TQC, a computationally interesting situations corresponds to non-Abelian anyons to guarantee that the states defining topological qubits form a higher-D space. This means that the swap $ab \leftrightarrow ba$ is not a commutative operation inducing a mere phase anymore. Since the status of Majoran fermions is unclear, it is still unclear whether any anyonic system satisfies this constraint. Galois groups are in general non-commutative so that this problem disappears.

Physical states would be Galois singlets and anyon-like states would be their building bricks just as quarks would define building bricks of general Galois singlets including also leptons and various bosons. Since Galois non-singlet cannot appear as a free particle, one could also understand topological entropy associated with anyons as relating to the entanglement with environment forced by Galois singletness in spin degrees of freedom.

Braidings and reconnections as basic elements of TQC

TQC in the TGD Universe involves also other new elements besides Galois groups.

1. The flux tubes connecting the nodes of a tensor net-like structure define natural candidates for braid strands. Both space-like and time-like braiding are possible.

   Time-like braiding defining TQC of the moving nodes connected by flux tubes induces a space-like braiding so that the TQC is recorded to memory as a kind of log file. Dance metaphor expresses this neatly: dancers at the parquette are connected by threads, which get braided and form a memory representation about the dance. This mechanism could define quite a general representation of memories based on space-time topology.

2. The fusion defined by the tensor product for the representation of the braid group or associated quantum groups is a key operation in standard quantum computation. The decomposition of the tensor products gives a superposition of topological qubits or more general qubit-like entities An interesting question is whether the fusion could have a more concrete topological meaning. Could the fusion of flux tubes correspond to a formation of a bound state of flux tubes inside a flux tube?

3. TQC as a braid generalizes to tensor-net (for tensor nets in TGD sense see [K46] [L34]). The nodes can have M incoming qubits and N outgoing qubits. The node corresponds to a quantum computation defined as a map between the incoming and outgoing qubits. In the framework, the nodes would correspond to CDs For $M \neq N$ is not a unitary transformation 1-1 transformation but can be an injection so that it is still an isometry at the level of the state space.

4. Besides swap as the basic braiding operation, also reconnection, having the same effect as far as initial and final states are considered, appears as a basic operation. When the incoming and outgoing qubits cannot move, reconnection could take the same role as swap and make TQC possible.

5. One can wonder whether this more general view about TQC could be realized in quantum biology. Could biochemical reactions correspond to fusions of braids of a tensor net, could reconnections and braidings make it possible to have a larger repertoire of TQCs. Could ZEO-based error correction requiring only time reversal play a key role in TQC.

Different TGD based views of TQC

TGD suggests several different perspectives of TQC.

1. In the flux tube picture, the basic elements are braiding, reconnections and fusions in which flux tubes could even form a bound state inside a larger flux tube so that the fusion could have a geometric meaning. At the level of H, fusion could correspond to a process in which the incoming particles arriving into the CD form a tensor product. Inside CD fusion occurs and gives rise to a decomposition of irreps. Measurement selects one irrep first and outgoing states are obtained by an SFR cascade reducing the total Galois group to the factors defined by relative Galois groups by a cascade of SSFRs defining cognitive measurements.

   Dance metaphor implies a mechanism of memory with spatial braidings representing spatial braidings. This mechanism would be realized in all scales and define kinds of topological Akashic records. If reconnection is equivalent with swap operation, then TQC is also possible without braiding induced by the motions of braid ends.

2. CDs are counterparts of gates at the level of H and define a fractal hierarchy of gates with sub-CDs defining sub-modules.

   Space-time surface in H can be also seen as a 4-D soap film with frames as seats of non-determinism and one could assign mental images with this non-determinism. This suggests that the gates at space-time level correspond to the frames whereas CDs would correspond to entire TQCs at the level of H. This also suggests that TQC in the TGD sense must allow intermediate SSFRs at the frames. The situation is far from obvious since fractality is also present and involves a hierarchy of CDs.

   The $M^8 - H$-duality provides a further view about TQC. A highly attractive idea is that TQC programs can be constructed as functional composites of polynomials giving rise to extensions of extensions of .... and inclusion hierarchies of corresponding Galois groups, each defining a normal subgroup of its sup-group.

   The normal subgroup hierarchy makes it possible to understand cognitive measurements as SSFR cascades reducing the representation of the Galois group to a product of representations for the subgroup and normal subgroup associated with it. This decomposition could generalize the decomposition of the anyonic representations. This would also suggest a deep connection with the paradigm in which computations are functions.

6.2 What could the replacement of the braid group with the Galois group mean?

The replacement of the braid group acting on anyons with the Galois group looks a rather innocent proposal first but has profound implications. The reason is that the Galois group permutes the roots of the polynomial P, which correspond to different mass shells in M^8 and therefore different values of light-cone proper time in H.

6.2.1 Functional composition of the polynomials and many-particle states

Functional composition of the polynomials is proposed to give rise to many-particle states.

1. The roots of P correspond to mass shells. Quarks have momenta at these complex mass shells. Roots and corresponding momenta are in general complex algebraic numbers and total momenta and mass squared values are real by Galois confinement.

2. Functional composite $P = P_n \circ ... \circ P_1$ of polynomials defines the interactions of particles in the number-theoretical picture. Functional composites are proposed to define particles as many-quark states and further functional compositions make it possible to engineer many particle states formed from these.

3. One can also consider iterates of a polynomial as analogs of many particle states involving only a single kind of particle. Functional decomposition gives as roots inverse iterates of the roots of the polynomial Q in $P = Q \circ Q... \circ Q$ [L59, L76, L77]. Asymptotically they give rise to an analog of the true Julia set (`https://mathworld.wolfram.com/JuliaSet.html`) as a boundary of the filled Julia set. The inverse iterates near the boundary of the Julia set would correspond to very nearly the same mass squared values and thus proper time constant hyperboloids.

4. One can regard the roots of P_i as roots with respect to the variable $y = P_{i-1} \circ ...P_1(x)$ if $y = P_{i-1} \circ ...P_1(x)$ defines the ground state coordinate. $h_{eff} = n_0 h_0$ would define a natural ground state for which $h_{eff} = nh$ would hold true.

5. If the polynomials appearing in the composite satisfy $P_i(0) = 0$, one has "inheritance of roots". The roots y_i of P_i are mapped to their inverse images $(P_{i-1} \circ ...P_1)^{-1}(y_i) = P_1^{-1} \circ P_2^{-1} ... \circ P_{i-1}^{-1}(x)$. This inheritance brings in mind conserved genes. A weaker form of "inheritance" would be that some polynomials, say $P_1, P_2, ..., P_k$ at the lowest level have $P_k(0) \neq 0$. For $P = Q \circ P_F$, where $P_F = x^2 - x - 1$ is "Fibonacci polynomial", the roots would be of form $(-1 \pm \sqrt{5 + 4y_n})/2$, where y_n is a root of Q. Note that one has $P_1(0) \neq 0$. If one has $P_k(0) \neq 0$ for $k > 1$, the roots of P_1 are roots of any P and therefore universal. This suggests the possibility that the ground state polynomial corresponding to $h_{eff} = h = n_0 h_0$ is non-vanishing at origin.

Ground state polynomial

The ground state polynomial P_g corresponding to $h_{eff} = h = nh_0$ is of special interest physically.

1. The arguments allowing to deduce the value of n_0 in $h = nh_0$ lead to a conclusion that the ground state polynomial P_g [L70] corresponding to $h_{eff} = h = n_0 h_0$ corresponds to a Galois group with $7!^2$ elements.

2. This allows several options. For instance, the semidirect product $S_7 \rtimes S_7$ could act as a Galois group. S^7 decomposes to a semidirect product of the simple alternating group A_7 and Z_2 acting as a normal group. S_7 can appear as a maximal Galois group for a polynomial of order 7. In this case S_7 could correspond to $Q_a = P_7 \circ P_2$ or $Q_b = P_2 \circ P_7$ and one would have four options $P = Q_i \circ Q_j$. Also $P_7 \circ P_7 \circ P_{2,a} \circ P_{2,b}$ $P_{2,a} \circ P_{2,b} \circ P_7 \circ P_7$ are possible.

3. Second roots appear in all basic formulas of quantum mechanics. Therefore one can argue that P_2 should appear at the bottom of the composite polynomial defining the ground state. Fibonacci quantum computation involves Golden Mean and the roots $x_\pm = (-1 \pm \sqrt{5})/2$ of Fibonacci polynomial $P_F(x) = x^2 - x - 1$. All roots would appear as pairs with members related by the Galois group of P_F. For $P_1 = P_F$ and $P_k(0) = 0$ for $k > 1$ (inheritance), the roots of P_F are roots of any P and Golden Mean would play a key role in fundamental physics.

Mass squared formula and inheritance hypothesis

For Galois singlets, the total momentum has components, which are ordinary integers. Also mass squared is integer.

1. If the stringy mass formula $m^2 = n$ holds true for the quark mass squared values as roots of a polynomial, one must have $m^2 = \sum m_i^2 = n$. This requires that the sum of the inner products

of quark momenta vanishes. The interpretation would be as an additivity of conformal weights. If every root is realized as quark momentum, $m^2 = \sum m_i^2$ equals the constant coefficient of the total polynomial P giving $m^2 = P(0)$.

2. If the strong form of inheritance holds true, one has $\sum m_i^2 = 0$ so that the total conformal weight vanishes. Could the interpretation be in terms of conformal invariance? Could one say that the tachyonic total mass squared assignable to the space-like states defined by braid strands compensates for the non-tachyonic total mass squared?

   Total momentum would be light-like and the $M^8 - H$ duality should be defined as the map $p^k \to m^k = \hbar_{eff} p^k/(p^0)^2$ where m^k belongs to the light-like boundary of CD containing the CDs assignable to the mass squared values as sub-CDs.

3. In p-adic mass calculations the total conformal weights are however non-vanishing and real. What could this mean?

   (a) The thermal excitations should be excitations of the $m^2 = 0$ state due to interaction with the environment, which extends the system. The thermal excitations would be described by polynomials $Q_{ex} = P_{ex} \circ P$. The roots of Q_{ex} would include, besides roots of P (inheritance), also the roots y_n of P_{ex} and these correspond to non-vanishing values of $P(y_n)$. $y_n \neq 0$ would give non-vanishing mass for the thermalized subsystem defined by P.

   (b) If one gives up the "inheritance" hypothesis and allows $P_i \neq 0$, one has $m^2 = \sum m_i^2 = P_n(0)$. Monic polynomials $P(x) = x^n + a_{n-1}x^{n-1} + ... + a_0$ are good candidates for the allowed polynomials. The coefficients a_k are integers so that the mass squared as a conformal weight $\sum m_i^2 = a_0$ is an integer.

Decomposition of Galois group to a product of relative Galois groups

The Galois group Gal for an extension of extension.... decomposes to a product of the relative Galois groups Gal_k/Gal_{k-1}.

1. One can speak of the ground state characterized by some Galois group Gal_0. Ordinary Planck constant h would correspond to Gal_0 and in [L70] it was proposed to be a product of permutation groups S_7 giving $n_0 = (7!)^2$. This allows to interpret CP_2 length scale squared as $n_0 l_P 2$, l_P Planck length. Galois group can be identified as a relative Galois group: as Galois group for extension of the extension defining the ground state.

2. The structure of the Galois group reflects the functional composition involving a large number of identical polynomials with the same mass spectrum as free particles. In the functional composite $P \circ Q$ the mass spectrum S of P is mapped to $Q^{-1}(S)$. Large number of iterations of P produces Julia set as a fractal. One can speak of an asymptotic mass spectrum.

3. The orbit of Galois group consists of mass shells and its cognitive representation can contain momenta at these mass shells.

   Galois symmetry would be a discrete symmetry connecting quarks with different mass values (which are counterparts of virtual masses rather than real masses). Galois symmetry would be analogous to a dynamical symmetry and would not commute with Poincare and Lorentz symmetries.

   Physical states are Galois singlets and have well defined real mass squared. Galois singlet property of physical states would imply that these symmetries would be respected. Physical states correspond to a CD containing sub-CDs... and at the lowest level there would be quarks. Essentially 4-D objects would be in question.

6.2.2 $M^8 - H$ duality at the level of M^4

$M^8 - H$ duality maps the algebraic physics at the level of M^8 formulated using polynomials to the geometric physics at the level of $H = M^4 \times CP_2$ formulated using variational principle and partial differential equations. The preferred extremal property required by general coordinate invariance

reduces the number of solutions of field equations so that they can correspond to a much smaller set of solutions of algebraic equations. The holographic aspects of $M^8 - H$ duality have been already considered and in the following only the map $M^8 \supset M^4 \to H \supset M^4$ is discussed.

1. $M^8 - H$ duality maps the surfaces of M^8 to minimal surfaces in H having singularities at which only the field equations for the full action containing also Kähler action besides the volume term hold true. $M^8 - H$ realizes holography: the mass shells determined by the roots of P can be continued to 4-surfaces containing them.

2. The precise form of $M^8 - H$ duality is not quite clear. The first question is whether one should allow complexification of M^4 as at the H side. One could define the H image as $M^k = \hbar_{eff} Re[p^k/m^2]$, where p^k is the quark momentum and at mass shell m^2. M^k would define some geometric objects in H. For physical states m^2 is integer and corresponds to a finite value of $a = \hbar_{eff}/m$. If the stringy mass formula $m^2 = \sum m_i^2 = 0$ is true, the image belongs to the light-cone boundary.

   The image could be a geodesic line of H parallel to m^k, which could start from the origin from the common center of CDs forming a fractal Russian doll hierarchy or from the tip of a given sub-CD.

   The image could also be identified as a point or a set of points. The point could be identified as the intersection of these lines with the boundary of the sub-CD defined by the mass value or its real part. Also the intersections with boundaries of all sub-CDs involved can be considered. Also the map of mass shells to M^8 to hyperboloids $a = a_n$, where a is light-cone proper time and a_n is inversely proportional to mass to realize Uncertainty Principle, makes sense.

3. The image of the orbit of the Galois group would correspond to a geodesic line starting at the centers or tips of various CDs defined by the mass shells. If the CDs are inside each other like a Russian doll, the geodesics intersect the $a = a_n$ hyperboloids and the boundaries of corresponding sub-CDs corresponding to different values of the light-cone proper time a and are time ordered. What is highly non-trivial is that the points at the orbit have time- like distances.

6.2.3 The orbits of the Galois group in H transform hyperboloids to each other

Mass squared values correspond to the roots a_n of a polynomial and are in general complex algebraic numbers. Their real projections can be negative and therefore tachyonic. The big surprise during writing of this article was the trivial observation that the Galois group permutes the mass shells defined by the roots of P.

If the real projections of mass shells to M^4 are mapped to H, Galois group can connect points with different values of complex "cosmic time" $a = a_n$. This does not conform with the idea that the particles of the physical state always have space-like distance but could conform with ZEO and non-determinism inspiring the view that time-like braiding is a physical state rather than its time evolution.

Note however that the spatial distance $(M_1 - M_2)^2$ in H is space-like for $(E_1 \geq m_1^2 + m_2^2)/m_2$ in the coordinate system in which M_2 and p_2 have a vanishing spatial part. This holds true also for the M^4 images.

Orbits of the Galois group as braidings?

Could the orbits of the Galois group for off-mass shell states be identified as braidings?

1. If the braiding is time-like, the value of the real part of the proper time parameter corresponding to the mass shells or CD sizes increases along the orbit.

   This would conform with the idea that the orbit of the Galois group consists of images of mass shells at the quark level. It also conforms with the breaking of Lorentz and Poincare symmetries at the level of the Galois group. This finding also justifies the Galois confinement: physical states correspond to a single value of a.

2. What about number theoretic anyons? These anyons must have non-trivial Galois quantum numbers and algebraic momenta. Here the relative Galois group is a convenient concept. Galois non-singlet property is with respect to the relative Galois group and one can forget the huge complexity of the Galois singlet ground state altogether.

Do Galois anyons require tachyonic states?

The momenta of quarks define the basic representation of the Galois group. One can also imagine representations in spin degrees of freedom. If only the spin degrees of freedom carry Galois quantum numbers, the space-time action of the Galois group is trivial. This does not look attractive and does not conform with time-like braiding. Anyon property therefore suggests the presence of tachyonic momenta.

1. I have played with the idea that quarks and also weak bosons appear in the scale of cells in living matter as dark quarks or even scaled variants with very small mass. How could the dark quarks manifest themselves?

   I have proposed that the protons of dark nucleon triplets representing codons are connected by meson-like bonds, which could be colored and confine codons to genes. This could the case also for the bonds connecting nucleons in the ordinary nuclei. Strong interaction would also make it possible to have dark neutrons.

   I have assigned the Z_3 Galois group with the dark nucleon triplets defining dark codons: this is required by the correct statistics in the model of the genetic code. Could Galois group Z_3 correspond to the center Z^3 of the color group $SU(3)$?

2. In the original proposal for DNA TQC [K3], quark triplets were indeed considered instead of dark nucleon triplets. Dark tachyonic electrons assignable to symmetric hydrogen bonded structures looks like a more realistic option. One can also consider mesons with quark and antiquark ends associated with the ends of the space-like braid strands. Dark tachyonic electrons could be associated with the ends of string world sheets for which the time dimension corresponds to a space-like normal dimension.

   Could one assign a colored quark pair to anyon-like electron? Leptohadrons [K105] are a basic prediction of TGD and there is empirical evidence for them. The predicted mass of the lepto-electron is very nearly the same as electron mass and evidence for its existence was found already in the seventies. Lepto-electron would be a color octet: this is allowed in the TGD framework.

   Lepto-hadron is associated with the breaking of parity symmetry in nuclear collisions involving strong electric and magnetic fields not orthogonal to each other. Its description involves Chern-Simons Kähler action associated also with anyons. The notion of induced gauge field allows its interpretation as SU(3) Chern-Simons action. A possible identification of lepto-electron would be as an anyon for which electron would be accompanied by a color octet quark pair formed by the quarks at the ends of the flux tube.

3. Polynomials can also have roots corresponding to space-like mass squared values. Could dark quarks be tachyonic in the sense that they have a negative real part of mass squared so that time direction as a normal direction for this object would be naturally space-like?

4. Could one see time-like braids structures as genuinely 4-D objects predicted by ZEO and the failure of the strict determinism of the action principle? Singularities as frames span 4-D soap films serve as a source of non-determinism.

How could dark DNA correspond to time-like braids strands for dark DNA?

The following represents a long list of cautious proposals represented as questions.

1. Can one Galois symmetries acting in time direction have projections acting effectively as 3-D symmetries of ordinary matter at time=constant surface.

   The Galois group at the level of (presumably gravitational) MB does not act at the level of ordinary matter. Could the time-like braids at the level of the dark DNA correspond to the

ordinary DNA strands in the sense that the temporal sequences would be mapped to spatial sequences by some simple rules?

2. Could genes have a representation as time-like braids? Could one imagine a pile of or ordinary DNA strands and their dark counterparts at different values of $a = a_n$ such that time like braid strands would have the same DNA content as the DNA in $a = constant$ or $t = constant$ plane. For instance, could the intersections of the points of cognitive representation at $a = a_n$ hyperboloids with $t = constant$ hyperplane define the DNA strand.

   The codons of dark DNA as a temporal sequence would correspond to codons of the ordinary DNA unless one assumes that only identical codons correspond to the orbits of the Galois group. This looks like a more reasonable option. Codons themselves would correspond to orbits of the discrete and finite subgroups of automorphisms of quaternions acting as symmetries of Platonic solids and regular polygons. Therefore two kinds of Galois groups would be involved.

3. Could the physical DNA correspond to the space-like braidings assignable to the time-like braidings of dark DNA? Could one realize the representations of the Galois group by using these projections at the level of ordinary DNA.

4. Could identical codons of a gene correspond to projections of points related by the Galois group? If so, the collections of identical codons (64 of them) would correspond to 64 orbits and the anyons would be realized at these collections as wave functions. Different representations would correspond to different anyons serving as number theoretical qupits.

String world sheet interpretation of time-like braidings at the level of H

$M^8 - H$ duality implies time-like braids correspond to physical states rather than time evolutions of an ordinary physical state localizable to time= constant hyperplane. The time-like character of states conforms with ZEO and is implied by the predicted non-determinism in which the singularities of the minimal surface correspond to loci for the failure of strict determinism. These singularities define analogs of frames for the space-time surface as an analog of a 4-D soap film. They are a necessary part of the data allowing to realize holography.

$M^8 - H$ duality [L57, L58] predicts candidates for the singularities as loci of non-determinism. The following argument suggests that the 2-D orbits of braid strands defined by string world sheets as fundamental objects of the TGD Universe giving rise to braidings could characterize the non-determinism.

1. 3-D light-like surfaces defining orbits of partonic 2-surfaces starting at the boundaries of CD and 2-D string world sheets connecting two light-like 3-surfaces. Strong form of holography, whose status is uncertain, states that only the partonic 2-surfaces at the boundaries of CD are needed.

2. String world sheets would provide additional data to fix the preferred extremal and the failure of 4-D determinism manifested as the failure of the minimal surface property would be localizable to the string world sheets. According to the dance metaphor, the ends of the strings would represent dancers and strings would represent the threads connecting their feet.

   String world sheets would be necessary for fixing the space-time surface. This is a profound deviation from string models, where data at time=constant section would fix the time evolution.

   In fully deterministic physics, the direction of time coordinate is normal to $t = constant$ slice. The normal directions of the string world sheet are analogous to time direction: that they are space-like conforms with tachyonicity. String world sheet would represent a tachyonic virtual particle exchange between particles with time-like momenta.

3. Also strings are minimal surfaces apart from singularities. Reconnection is a singularity at which the string world sheets intersect at a single point and involves failure of determinism. The effect of reconnection is the same as that of braiding (SWAP). Reconnection therefore corresponds to the SWAP gate in TQC.

4. The 4-D character of the space-time surface implies that the strings develop spatial braiding during the dance and can also reconnect. This does not happen in super string models with 10-D embedding space for strings.

   The braiding and reconnection patterns would represent the time evolution of string-like entries in 4-D space-time so that TQC would reduce to a string model-like theory with one important exception: braiding and reconnections are not possible in string models.

   Gravitational flux tubes would be one particular case of flux tubes. They seem to be key players in biology and provide a quantum gravitational view about metabolism, biocatalysis, and DNA [L81]. TQC involves braiding and flux tubes with strings attached with them: TQC would have a direct connection with string model type description of quantum gravitation and other interactions.

Tachyonicity of the time-like braids as physical states could be therefore understood. One can look at the situation also from the point of $M^8 - H$ duality to gain additional perspective.

1. Virtual particles of QFT picture would in TGD framework have a discrete mass squared spectrum give by the roots of a polynomial and thus algebraic, in general complex, numbers [L76, L77]. Their finite number in zero energy state would resolve the divergence problem of QFTs.

   Only quarks appear as fundamental fermions. Mass squared values and momenta of many quark states constructed are in an extension of rationals without the condition of Galois confinement implying stringy mass squared spectrum and integer valued momentum components using the scale of CD as unit.

2. Quarks at mass shells of $M^4 \subset M^8$ are mapped to geodesic lines of H by $M^8 - H$ duality. They can be also space-like unless one assumes that the real parts of the roots of P are non-negative. For negative real parts, the momenta would be space-like and define points outside the sub-CD but a larger CD could contain them.

   Could the total momentum of say 3-quark state possibly associated with codon (3N quark state associated with a gene) be tachyonic? Could the tachyonic quark triplets be located along the time-like braid strand associated with the codon and define a tachyonic many-quark states?

3. For anyons as tachyons Galois confinement must fail and they should correspond to virtual states made from quarks. Could the strands of a space-like braid as a string with quark and antiquark at its ends define an entity analogous to a virtual meson? Could this meson-like entity have non-trivial color quantum numbers?

   How do Galois confinement and color confinement relate? At the level of "world of classical worlds" (WCW) quark color corresponds to partial waves in CP_2 for cm degrees of freedom for the partonic 2-surfaces associated with quark. At the level of the space-time surface there are no color partial waves since fermions do not have color as a spin-like quantum number. I have proposed a Z_3 subgroup of the Galois group as a counterpart for $Z_3 \subset SU(3)$. Correct statistics requires antisymmetry with respect to Galois Z_3.

   One must take this with caution: maybe the braid statistics of anyons could solve the statistics problem. Note however that braid statistics is analogous to Fermi statistics in that two particles are not possible in the same state.

The original proposal for DNA as a TQCer, was that DNA and nuclear membrane are connected by flux tubes having quark and antiquark at their ends. Also DNA strands would be connected by this kind of strands. The proposal was motivated by the observations and the classical counterpart of color gauge field is proportional to the induced Kähler form, and can define a coherent field in arbitrarily long scales.

I gave up this proposal a long time ago but it seems that this proposal had some seed of truth in it. Anyonic electrons replace quarks and antiquarks.

1. What comes in mind first is that the DNA strand and its conjugate involve, besides dark nucleon triplets, also dark quark/antiquark triplets forced by the time-likeness of the braiding

regarded as a physical state in ZEO. This however leads to problems since dark nucleons are strongly favored. Doubling of the genetic code without need for it looks ugly. The mere quantum gravitational modification of the standard chemistry should be enough.

Most importantly, tachyonicity does not require single quark states. Also the dark anyonic electrons could be virtual particles carrying tachyonic momenta. The 3+3 dark electrons assignable to the asymmetric HBs of form O..H-N would provide electronic realization of the genetic code. The dark codons would serve as names, addresses in the symbolic dynamics of TQC involving the resonance mechanism of communications requiring addresses.

The dark anyonic electrons assignable with G-C bonds would carry tachyonic momenta and make the braiding possible. The tachyonic electronic momenta assignable to bonds symmetric O...H-O type bonds connecting water molecules and phosphates would be realized in the same way.

2. It is good to bring in mind the possible weak points of the scenario once again. Dark protons are strongly suggested by the Pollack effect and the proposed picture about dark gravitational HBs with delocalized dark protons [L81]. In the original view, dark protons screened the negative charge of phosphates. In the new picture the negative charge of phosphate is assignable with bi-localized (anyonic/dark/virtual) electrons of O...H-O +O-H...H: at the level of ordinary matter, DNA is not negatively charged. In QFT language, one might perhaps say that a dark electron is exchanged between the ends of the flux tube associated with the dark HB.

Connection with time-like character of music experience and cognition

A connection with the model of DNA based on bioharmony is suggestive.

1. DNA and RNA codons are identified as points at the orbits of icosahedral and tetrahedral subgroups of quaternion automorphisms. Amino acids (AAs) have been identified as orbits of the icosahedral and tetrahedral groups, which are discrete subgroups of quaternionic automorphisms, which is completely analogous to Galois groups.

2. Harmony is the basic element of music and music involves time in an essential way. Same is true of cognition. Perhaps the time-like braid strands could give a concrete content to the proposal. Codons would correspond to 3-chords and gene would correspond to a piece of music in a much more concrete way than originally proposed. Genes would also represent primitive cognitions.

6.2.4 Cognitive measurement cascades as counterparts of measurements of anyon charges

The measurements of topological charges reduce the tensor products for the representations of the braid group to irreducible representations. What would the counterpart for this process be at the level of the NQC?

1. I have discussed cognitive measurements [L27, L62] as a cascade of "small" state function reductions (SSFRs) for the irreducible representations of the Galois group of extensions of extensions of.... . The full Galois group has a representation as a product of relative Galois groups $R_n = Gal_n/Gal_{n-1}$. The SSFR cascade means a reduction of the representation to a product of representations of the relative Galois groups R_n.

2. This measurement cascade would be the opposite for the measurement of anyonic topological charges involving an analogous decomposition of the tensor product of representations to irreducible representations of the full braid group.

   In ZEO, the counterpart for the measurement of topological charges would correspond to the time reversal of this process starting with BSFR, which creates a completely entangled state as the representation of the full Galois group, and is followed by SSFR cascade proceeding in an opposite time direction. The formation and decomposition of tensor products would occur in different time directions.

6.2.5 Comparison of standard view about TQC with the TGD view

It is useful to compare the standard view about TQC with its TGD counterpart.

1. Qubits as states are replaced by representations of the braid group characterized by the value of the topological charge and of the quantum group G assignable to the Chern-Simons action.

   Quantum groups [A30, A8, A19] are discussed from the TGD point of view in [K12] and in chapters about possible role of von Neumann algebras known as hyperfinite factors of type II_1 in TGD [K110, K39].

   Quantum group $SU(2)_q$ quantum group characterized by quantum phase $q = exp(i\pi/k)$, $k = 5$, is the simplest option. One can say that anyons correspond to electrons assignable to the orbits of 2-D systems, whose time evolution could be described by Chern-Simons action.

   In TGD, these 3-surfaces would correspond to the light-like orbits of partonic 2-surfaces which for larger values of h_{eff} can have rather large size. For $h_{gr} = GMm/v_0$ the gravitational Compton length for a particle with mass m is $GM/v_0 = r_s/2v_0$ independent of the mass of the particle and for Earth this gives .45 cm for $v_0 = c$, one half of the Schwartschild radius.

2. Topological qubits correspond to topological charges such as the already mentioned parity for condensed matter Majorana electrons, which would have degenerate energies because they correspond to momentum vectors k and $-k$ differing by lattice momentum.

3. Quite generally, quantum measurements are Hilbert space projections. Measurement of qubit corresponds to a measurement of a topological charge. The qubit can be measured by a fusion process for the representations of the gauge group G. Fusion means a formation of a tensor product of representations and could result as a final state of TQC. Measurement means a projection to a particular representation characterized by a topological charge.

   One can also consider the opposite operation in which one decomposes a given representation to a direct sum of product representations and projects out one particular product representation by measuring topological charges for the composites.

4. Fibonacci TQC with quantum group $SU(2)_q$ for quantum phase $q = exp(i\pi/5)$, serves as the simplest candidate for an interesting TQC. Condensed matter Majorana fermions could correspond to Fibonacci anyons with $q = exp(i\pi/5)$ (`https://phys.org/news/2014-12-fibonacci-quasiparticle-basis-future-quantum.html`). The fusion for Fibonacci anyons is non-commutative and non-associative. These properties are coded by a non-commutative R matrix and non-trivial F matrix (see Appendix). For a fusion of N representations the number of degenerate ground states is N:th Fibonacci number.

   This has a counterpart in TGD.

1. In the TGD framework, Galois group elements in general change the value of cosmic time as a real part of the root of the polynomial defining the mass shell in M^8 and its image in H. Therefore the associated virtual quark states are not energy degenerate.

   That mass squared values for anyons are different conforms with the idea of time-like braiding as a genuine quantum state rather than time evolution of quantum state, which is natural in ZEO. One can of course challenge this assumption. For states containing N particles with the same polynomial P and represented as an iterate $P \circ .... \circ P$ mass squared values as roots approach to Julia set for P, and this could give rise to approximate degeneracy of mass squared values and corresponding values of light-cone proper time a.

   One can also consider a situation in which one has several roots with the same real part (say roots of a second order polynomial). One can ask whether the analogs of condensed matter Majorana fermions correspond to these kinds of states.

2. The topological structure in question would be realized in terms of the space-time topology as a monopole flux tube not possible in Maxwellian electrodynamics. Also the strings assignable to the flux tubes and corresponding string world sheets as representation of time-like braiding inducing space-like braiding would play a key role. Chern-Simons action would be assigned to the light-like 3-surfaces defining the orbits of partonic 2-surfaces and string world sheets would connect these orbits.

3. The quaternionic automorphism group, defining the analog of the Galois group and having $SU(2)$ or its quantum variant as a covering group, serves as the analog of the gauge group G and acts in the normal space of the space-time surface. Discrete and finite subgroups assignable to the Platonic solids and regular polygons define the natural finite discretizations of this group.

   The braid group could be replaced with a subgroup identifiable as the Galois group for an extension of rationals or for extension of extension of rationals. Also this group can be non-Abelian and would be naturally represented as a subgroup of the braid group.

4. Time reversed fusion corresponds to a cognitive measurement cascade consisting of unitary evolutions followed by SSFRs as counterparts of "weak" measurements. Cognitive measurement cascade and its reversal are initiated by a BSFR changing the arrow of time. Two subsequent BSFRs would correspond to fusion and its reversal and the time evolution between them would correspond to the braiding as a unitary evolution. In TGD inspired theory of conscious experience, the sequence of SSFRs gives rise to the flow of consciousness.

5. Quantum group $SU(2)_q$ for Fibonacci TQC has an interpretation as quantum automorphism. What makes this biologically highly interesting is that the twist $exp(i\pi/5)$ is realized geometrically in the structure of the DNA. This suggests that DNA and dark DNA could involve TQC. One can wonder whether genes with N codons correspond to a fusion of N Fibonacci representations.

6.2.6 Could the MB of DNA perform intentional TQC?

In TQC and also in AI as human endeavours, human intention plays a key role. This fact has been often forgotten by AI extremists. The braiding defining the TQC would be constructed using technological tools developed by humans. What about the situation at the level of DNA based TQC? Could the MB of DNA play the role of humans to some degree? What kind of quantum computations could the MB of DNA perform?

1. When the braid ends can participate in the flow defined by cellular water or by 2-D liquid defined by the lipids of the cell membrane in liquid crystal phase, one can consider the possibility that the MB induces this flow and in this way builds time-like TQC program, which is also stored as spatial braiding to memory.

   As will be found in the next section, this situation would be true for braids possibly defined by the gravitational flux tubes connecting the oxygens of phosphates of DNA with the lipid ends of nuclear or cell membrane containing also phosphates. Also the GTPs and GDPs of microtubules contain phosphates and their oxygens could be connected with those of lipid phosphates.

   The braiding would serve a memory storage purpose. If MB can induce the flow of water or of lipids, one can say that it can build TQC programs. For instance, a representation of function involving two registers could be constructed by starting from entangled register and using the flow of water or lipids to induce the needed braiding for the second register implying the entangled state $\sum |n\rangle\langle f(n)|$. The TQC ending with cognitive state function reduction cascade would define a conscious cognitive representation of the flow.

2. It will also be found that A-G base pairs by the N...H-N $\leftrightarrow$ N-H...N symmetry of gravitational flux tubes define candidates for HBs assignable to TQC. In this case the braid ends cannot move but the reconnections of braid strands could produce braiding and TQC. Similar situation is true for the sequence of identical DNA codons of, say, genes. They could define an orbit of the Galois group and give rise to its representation. There would be 63 types of orbits which could decompose to separate representations corresponding to various codons. Besides single electron states also many electron states would be possible.

   In this kind of situation, the cognitive measurement cascade would give rise to a conscious cognition at DNA level. In ZEO, reconnections would be forced by the preferred extremal property and unavoidable by the 4-D character of the space-time surface. Therefore they

would reflect the underlying physics. The failure of the strict determinism could be interpreted as a selection between a finite number of alternatives at the frames defining the space-time surface as a 4-D analog of soap film. The analog of TQC would give rise to a sensory perception accompanied by cognition.

Factorization of integers into primes is one of the most interesting applications of QC. At first, it looks unlikely that the MB of DNA could be able to do something like this. However, finite groups have a prime decomposition to a product of finite groups and in the same way Galois groups have a decomposition to a product of relative Galois groups, which do not have a similar decomposition.

Group theoretical prime decomposition is analogous but more general than the prime decomposition of integers and more general composition of algebraic numbers to algebraic primes. Since groups with a prime number of elements are certainly prime groups, prime factorization would follow as a consequence and would be a side product of any cognitive SSFR cascade. This conforms with the paradoxical finding that idiot savants, who do not have any idea about the notion of prime, can factorize large integers [L32].

Could Quantum Fourier Transform (QFT) have any analog at the level of DNA? The states in the irreps of the Galois group serve as candidates for the plane waves defining Fourier components. Could cognitive measurements naturally involve a measurement of these quantum numbers as eigen values for maximal set of commuting Galois group elements acting as a minimal Galois transformation. For instance, a rotation by $exp(i2\pi/n)$ would be analogous to this kind of transformation in Z_n. These measurements would induce a localization to a single Fourier component and repeated measurements of the same state would give the probabilities of various Fourier components. These states are superpositions of states at mass shells with varying mass squared and involve time delocalization making sense by the finite non-determinism. A repeated measurement of Galois momenta would make it possible to find the factors of an integer as in the ordinary QC.

6.3 DNA as quantum gravitational TQCer?

In this section a detailed model for DNA as a TQCer will be developed. The attribute "quantum gravitational" is not necessary since also smaller values of h_{eff} than h_{gr} can be considered.

6.3.1 Concrete questions concerning DNA TQC

Before representing a concrete model for TQC using Galois anyons as qubits, the basic questions are discussed.

How could DNA qubits be realized physically?

For TQC temperature topological charge identifiable replaces spin as qubit. In the TGD framework Galois charges replace topological charges and one can talk about Galois anyons.

The basic question is how DNA makes it possible to realize anyonic qubits.

1. Dark nucleons associated with dark DNA codons, that is with O...H-O type HBs cannot realize dynamical qubits in terms of spin because the codons must be fixed if they are to represent genetic code. Only in the communications based on resonant cyclotron transitions their states can temporarily change but should return back to the original state as a state of minimum (free) energy.

   One can assign to A-T, G-C pairs 1+1 asymmetric HBs, which do not allow electronic anyons. This gives rise to 3 +3 dark electrons, which could give rise to dark representation of the genetic code.

   The tentative interpretation is that the dark codons define the analog of computer hardware with a fixed ROM. The dark codons would serve as addresses in the resonance mechanism: the analogy with LISP is obvious.

2. The dynamical working memory should correspond to an anyonic realization of qubits. A dark electron associated with the quantum HB of type X...H-X +X-H...X can give rise to two

bi-localized states with odd and even Z_2 parity where Z_2 exchanges the ends of HB. These two dark electron states could serve as anyons.

This could work for electrons of O...H-O bonds between the oxygens of phosphate and water molecules. This could be also the case for the N...H-N bond of C-G base pair, which is symmetric. The HB can be assigned with C codon. In this case, the notion of Z_2 anyon makes sense and could make possible TQC using gravitational variants of symmetric HBs of C-G base pairs (`hhttps://cutt.ly/WGNddJ3`).

How could the unitary time evolution be realized?

Superpositions of HBs of type X...H-X + X-H...X could give rise to electronic anyons with bi-localized dark electrons. Depending on the situation, braiding or reconnections having, at least apparently, the same effect would define the unitary gates.

1. If the molecules containing X can move, braiding is possible. This is the case if the HBs are associated with the phosphates of lipids of the cell membrane forming a liquid crystal and connect them to the molecules of the cellular water. In the sol phase for intracellular water, the flow of water molecules could define braiding.

   The original proposal [K3, K106] was that the flux tubes connecting the oxygens of the phosphates associated with the DNA strand with the phosphates of the lipid ends would define TQCer. The flow of the lipids of the lipid layer forming a 2-D liquid could define a braiding and thus TQC program. For gravitational flux tubes this option could make sense. The oxygens of the phosphates of DNA could be also connected with the molecules of the water surrounding the DNA if they can move.

   In this case, the dance metaphor makes sense: the TQC as time-like braiding produces a log file as a spatial braiding.

2. For N..-H-H + N-H...N HBs of C-G base pairs the nitrogen atoms cannot move. The reconnections of dark braid strands could produce the same effect as braiding and induce flux tube connections between C:s and G:s belonging to distinct C-G pairs. For gravitational flux tubes these connections could be very long.

   String word sheets are fundamental objects in TGD and by the 4-dimensionality of the space-time surface, 2-D string world sheets at flux tubes representing the orbits of space-like braids intersect at a discrete set of points and for preferred extremals the reconnections are forced by topology. The non-determinism is associated with the choice whether the time-like strand pair AC+ BD transforms to AC+BD or AD+BC.

What about ordinary QC or TQC using electron spin of HB as qubit?

I do not understand TQC enough to say whether electron spin could also appear as a qubit when braidings and reconnections define the gates. In any case, this option meets the same objections as the QC option since a very low temperature would be needed in the standard physics framework.

1. The hyperfine splitting (`https://cutt.ly/oGNdeA3`), causing the 21-cm line of hydrogen, corresponds to the magnetic interaction energy of nuclear dipole moment with electron's magnetic field and is proportional to h_{eff}. The energy of hydrogen hyperfine splitting is $\Delta E = 5.89 \times 10^{-6}$ eV. This corresponds to a temperature of 5.89×10^{-2} K. If the electrons are dark, the energy of hyperfine splitting is proportional to h_{eff}. The energy is above thermal energy at room temperature for $h_{eff}/h > 5 \times 10^3$.

   Note that the temperature T at the MB of DNA is assumed to be very low but during aging identified as an approach to thermal equilibrium with the biological body T is assumed to increase and approaches the Hagedorn temperature assignable to the flux tubes of MB [L101].

2. If spin serves as a qubit, the manipulation of electronic qubits by changing their spin direction using photons or braiding or reconnection, which at least apparently seems to have the same effect as braiding, would be needed. Both braiding and reconnection involve the replacement $A \to C + B \to D$ with $A \to D + B \to C$ but reconnection involves temporary touch of the braid strands which might have some effect.

6.3.2 Number theoretical generalization of Kitaev's proposal

Kitaev [B8, B7] has proposed an elegant model for TQC using as qubits the two states of condensed matter Majorana fermion [D18] with two bi-localized states, which have parities +1 and -1 under Z_2 symmetry.

Galois group as subgroup of braid group and Galois anyons

In the TGD framework, the representations of the Galois group would naturally replace these representations and one could speak of TQC which is also number theoretic as far as anyon-like states are considered.

Topological robustness would be replaced by number theoretical robustness due to the fact that the extension of rationals depends only weakly on the polynomial: this is obvious from the fact, the number of extensions is finite for a polynomial of given degree. M^8-H duality [L57, L58] indeed implies that a given space-time region is determined by a polynomial. In QFT approximation one is forced to replace many-sheeted space-time with ordinary space-time and the nice picture is lost. One might however hope that in TQC this loss is fatal.

1. Galois group replaces Z_2. Instead of topological charges, one can speak of number theoretical charges. Representations of the Galois group would correspond to number theoretical qubits. Number theoretical anyon would be identified as a superposition of states localized at points of orbit of Galois group Z_2 associated with DNA double strand.

   As already found, the Galois ground state corresponding to $h_{eff} = h = n_0 h_0$ is not completely unique but would naturally correspond to a polynomial $P_g = Q_g \circ P_2$ where P_2 is second order polynomial, all roots of $P = P_1 \circ P_g$ appear in pairs $x \pm y$ and Z_2 permutes the members of the pairs. Fibonacci polynomial $P_F = X^2 - x - 1$ is highly attractive candidate for P_2 and would give the roots $(1 \pm \sqrt{5})/2$ as roots of all polynomials P. Also the twisting geometry of DNA favors Fibonacci TQC, which is also the minimal option.

2. Hydrogen bonds X...H-X and X-H...X are symmetric and their possibly gravitationally dark variants, could give rise to states with opposite parity. The electron of the hydrogen could define the number theoretic anyon.

3. The gravitational flux tubes as counterparts of H-bonds could define the braid strands but alsos smaller values $h_{eff} \geq h$ assignable to electromagnetic flux tubes could work. Braiding would take place for these strands.

4. What about the protonic option for X...H-X type HBs based on the identification of anyons as delocalized states of the dark proton with opposite parity? Also now one can consider a superposition of N-H...N and N...H-N gravitational bonds and two different parity states with respect to Z_2. The quantum gravitational model for the metabolic energy quanta however suggests that the dark proton is localized mostly in the interior of the gravitational flux tube so that the dark proton should not have a large amplitude at the ends of the flux tube.

Hydrogen bonded structures of type X...H-X populate living matter. Water and DNA and the first examples that come into mind.

1. The hydrogen bonds between water molecules are of type O..H-O. Hydrogen bonded water molecule clusters could give rise to multiply localized anyonic states of electrons and serve as TQCers.

2. The HBs of the oxygens of phosphate atoms with oxygens of water molecules allow poly-localized electrons if the HB is superposition of O-...H-= and O-H...H. This would allow to associate electronic anyons and TQC also with the dark nucleon triplet codons, which cannot have dynamical spin.

3. G-C base pair has one N..H-N type HBs (`hhttps://cutt.ly/WGNddJ3`). N-H...N $\leftrightarrow$ N...H-N are could be possible for $h - eff > h$ HBs, and could lead to the delocalization so that one could assign anyonic state with Galois Z_2 symmetry with it. The G-C base pairs of the DNA double strand could define a sequence of topological qubits. Note that the splitting of

the N-H...N bond in the G-C base pair leading to N + H-N is known to occur during DNA transcription and replication and also in the temporary splitting of the HB [L81].

4. Benzene allows delocalized states of electron pairs, which could be poly-localized and be analogous to Z_6 anyons. Also Z_2 and Z_3 anyons can be considered. The atoms of the aromatic ring could be connected by flux tubes with $h_{eff} > h$ and perhaps even $h_{eff} = h_{gr}$.

   In DNA , the sequences of the aromatic 5- and 6-rings, possibly defining Z_5 and Z_6 anyons, could give rise to a delocalization of the anyonic states along DNA strands possibly involving gravitational analogs of valence bonds.

5. In DNA strand nucleotides A and G contain aromatic 5- and 6- rings glued together whereas T and C contain aromatic 6-ring (`hhttps://cutt.ly/WGNddJ3`). The members of base pairs contain fused 5- and 6-ring and 6-ring respectively. One can wonder whether the Galois representations associated with these structures in the double DNA strand structure could make possible TQC. Also the side chains of amino acids Phe, Tyr, and Trp contain aromatic rings and HBs between oxygens of water molecules might be relevant for information processing at, say, microtubular level.

The non-symmetric HBs of base pairs and possible new dark realizations of the genetic code

The symmetric HBs of C-G base pairs (`hhttps://cutt.ly/WGNddJ3`) would be in a very special role. What about the remaining non-symmetric HBs associated with codons?

1. Besides N..H-N HB there are 3+3 electrons per codon with asymmetric HB of form X..H-Y, with X,Y= O,N or N,O. The proposal that an electronic variant of metabolism is realized, leads to the question of whether the spins of these 6 electrons could realize genetic code as a 6-bit code. Now only the analogs of DNA codons would be realized.

2. For asymmetric HBs, anyonic dynamics for electrons is not possible but the electronic dark codons could serve as addresses in the resonance mechanism of communication based on the transformation of Josephson radiation to pulse sequences by cyclotron resonance [L88, L81]. This is possible if the electrons are dark so that the energy of the hyper-fine splitting is scaled so that it is higher than thermal energy. This would require $h_{eff} \geq 50$.

   One can also imagine resonance-based communications between dark electron 6-plets and dark nucleon triplets using dark photons.

3. The dark proton at flux tube and dark electron at the hydrogen end could define an analog of dark H atom. Dark H would have 4=3+1 spin states with spins 1 and 0 and these states could define the analogs of nucleotides in 1-1 correspondence with A,T,C,G. C as a special codon would naturally correspond to the spin singlet. Hyper-fine splitting for this dark atom would distinguish between triplet and singlet. For large h_{eff} the energy this splitting would be above thermal energy so that the spin configurations would be stable.

These observations challenge the details of the earlier view [L88] about the genetic code.

1. The dark nucleon realization of the genetic code [L88] predicts both DNDA, DRNA, DtRNA, and DAAs. One can criticize the realization since also neutrons are required.

   The model of the code has several variants but the most recent model [L81] requires dark variants of both neutron and proton residing at the gravitational flux tube defining gravitational HB connecting the oxygens of phosphate and water. The charge of the delocalized dark proton would not be visible in the scale of DNA so that its replacement with dark neutron would not affect the situation in this scale.

   Dark protons would be generated from ordinary protons in Pollack effect [I107, L22, I140, I128]. They could transform to dark neutrons by the dark variant of strong interactions or of weak interactions at the gravitational flux tubes. Dark weak interactions could be realized in even cellular scales and imply that dark variants of weak bosons are massless

in the scales below the dark Compton length of weak bosons. This would explain chiral selection of biomolecules difficult to understand in the standard model.

The conserved vector current hypothesis (CVC) and partially conserved axial current hypothesis (PCAC) [K105] relate the descriptions of hadrons in terms of strong and weak interactions, which suggests that these views might provide dual descriptions. The duality might in fact reduce to M^8-H duality. The interpretation of anyonic electron as a color octet electro-pion [K105] involving color octet meson-like state associated with the gravitational flux tube was already discussed.

If HB is associated with oxygen of phosphate (water molecule), the hydrogen of phosphate (water molecule) would look negatively charged. For anyonic states the electron of H would spend half of the time near the two oxygens involved implying that negative charge would be delocalized in a longer scale.

2. Could the standard genetic code be associated with the electron triplets at HB associated with base pairs rather than with the phosphate water HBs? One can imagine two realizations.

   (a) For both dark DNA strands, both dark proton triplet and dark electron triplet would have 2^3 dark entangled states and together they would combine to form 64 states. Could they provide a dark realization of the genetic code consistent with the chemical genetic code?

   (b) Could the dark protons at the HBs associated with base-pairs pair with dark electrons at their ends give rise to analogs of dark H atoms? This could give 64 states perhaps allowing an interpretation as a dark realization of genetic code.

   There are objections against both proposals. The counterparts of RNA,tRNA, and AAs are not predicted so that the correspondence with the chemical realization of the genetic code is not plausible. Dark codons would have integer spin varying from 0 to 3 and the code table does not show any grouping of codons to these multiplets containing an odd number of states.

To sum up, it would seem that several realizations of the genetic code are possible as indeed suggested by the proposed universality of the genetic code [L68, L88].

Could protonic and electronic anyons define a pair of registers?

Two registers are needed to represent a Boolean function $x \to y = f(x)$ in terms of entanglement (see Appendix). n qubits represent the values of x and y. The simplest representation of f is as a maximally entangled state $\sum |n\rangle\langle f(n)|$. In this representation quantum Fourier transform (QFT) is exponentially faster than the ordinary fast Fourier transform. Also the quantum counterparts of number theoretic algorithms such as finding prime factors and greatest common divisor are faster than their classical counterparts.

How could one realize these registers in the recent case? There should be a natural interaction inducing the entanglement between qubits. The realization of the genetic code fixes the states of dark proton and electron triplets completely for a given codon so that these qubits are non-dynamical.

In the case of HBs of type X...H-X, this however leaves the anyonic degrees of freedom assignable to the dark electron as Z_2 degeneracy and perhaps also with dark protons as a similar degeneracy. The entanglement between electronic and protonic anyons would commute with the spin degrees of freedom. Could the two registers correspond to electronic and protonic anyons? Could the braidings of the flux tube, possibly induced by reconnections, generate entanglement between these anyons? The objection is that the anyonic dark protons would not be delocalized in long scales as the model for metabolic energy quantum requires. The metabolic dark proton states would correspond to different states concentrated near the top of the gravitational flux tube.

6.4 Appendix: Basic concept and ideas of quantum computation

I am not a specialist in quantum computation and since some readers might also have the same problem, I have added some remarks about QC, which I believe to be relevant for this article. I have discussed the TGD view about TQC for about 13 years ago [K4, K3, K106]. These chapters reflect my views at that time and a lot has happened in the TGD based view of quantum biology after that. Perhaps I also have a little bit deeper understanding of TQC now.

6.4.1 About key ideas of QC

In the following the basic ideas QC and TQC are briefly described.

Gates as unitary transformations

Quantum computation can be seen as circuits consisting of gates, which realize unitary transformations assigning to n incoming qubits $n = m$ outgoing qubits: unitary forces $m = n$. For qubits, which reduce to ordinary bits one obtains as a special case Boolean functions from n to n bits.

Unitarity forces $m = n$ but by using control qubits for which nothing happens in the gate but the outcome from the remaining qubits depends on the value of the control qubit, one can realize also gates which for bits reduce to Boolean maps from n bits to a smaller number of bits so that ordinary logic circuits can be realized as a special case.

n-gates with $n = 1, 2, 3$ are enough for obtaining a universal set of gates. The interested reader can learn details from the slides of Viterbi: for instance the slides at `https://cutt.ly/EGNsmcR` describe Quantum Fourier Transform.

1. 1- port represents a unitary transformation of a single qubit.

   (a) Phase gate, Hadamard gate and rotations by Pauli spin matrices are basic gates of this kind. Discrete rotation as $SU(2)$ transformation represents the general unitary transformation. Rotation is specified by two orthogonal rotation axes and by 3 rotation angles.

   (b) Discrete subgroups of rotation group assignable to Platonic solids and regular polygons define especially interesting selections for the set of possible quantization axes and for the possible directions of spin representable as a point of Bloch sphere. For Platonic solids the subgroup of $SU(2)$ is discrete. These subgroups can produce unitary transformation in a finite accuracy only but one can consider the possibility of transformations obtained as products of elements of these subgroups.

   (c) Quantum variant of $SU(2)$ emerges in TQC and also the braid group defines a quantum variant of the permutation group as a finite covering of the braid group. The gates in topological computation correspond to the elements of the braid group. In the TGD framework, $SU(2)$ has a representation as the covering of the automorphism group of quaternions (analogous to Galois group) acting in the normal space of the space-time surface.

2. Arbitrary $N \times N$-D unitary transformation can be constructed as a product of 2-D unitary transformations. In the $N = 2^n$ case, the transformation can be represented at qubit level and using control gates one can represent unitary transformations by using qubit representation with $N < 2^n$.

   The representation of a general unitary transformation in dimension n requires of order $n2^n$ gates. The subset needed as unitary transformations is however believed to be much smaller than all possible transformations.

3. Swap, which permutes subsequent incoming qubits and CNOT are examples of 2-gates.

4. The notion of controlled gate generalizes to n qubits. Toffoli gate as CCNOT defines a 3-gate and together with 1- and 2-gates it defines a universal set of gates.

Bloch sphere and Platonic solids

Block sphere gives a parameterization for the directions of the spin quantization axis and spin has two directions for a given quantization axis. In the twistorialization of TGD at the level of M_c^8 this interpretation of the twistor sphere is natural [L57, L58].

1. In the number theoretic vision these directions correspond to sines and cosines and in the number theoretic vision these must belong to the extension of rationals considered assignable to a given space-time region. This discretization can be interpreted in terms of finite measurement resolution.

2. The allowed quantization directions are obtained from each other by the transformations of the rotation group $SU(2)$. If these rotations form a finite group, only the symmetry groups of Platonic solids and regular polygons are possible. For Platonic solids there are 4, 6, 8, 12, and 20 quantization axes corresponding to tetrahedron, octahedron, cube, icosahedron and cube.

Some applications of QC

Examples of the applications of QC working faster than their classical counterparts are discussed in the Wikipedia article (`https://cutt.ly/8Hs5qdG`). For instance, the following examples are discussed.

1. A very simple application is the finding of the inverse image of function by measurement the of value of function $f = f(n)$ for $\sum |n\rangle\langle f(n)|$ giving the superposition $\sum |n\rangle\langle f(n) = y|$.

   In a more general case this localization gives the inverse image of a map f of m-D discrete space to n-D discrete space. The repeated application of this algorithm can be used to find the boundary of a region of the inverse image of f.

2. Quantum Fourier transformation calculates a discrete Fourier transformation exponentially faster than ordinary fast Fourier transform. Other related applications find a prime factor of integer, period of a periodic function represented as an entangled state $\sum |n\rangle\langle f(n)|$ of two registers as, and number theoretic logarithm.

   Quantum Fourier transform (QFT) is discussed (`https://cutt.ly/EGNsmcR`) takes place exponentially faster than the classical fast Fourier transform. For $N = 2^n$ qubits the number of computation steps is $O(n)$ whereas classically it is $O(n2^n)$. The discrete Fourier transform has a huge number of both physical and number-theoretical applications.

   QFT can be represented in terms of n qubit registers as an un-entangled product of states of n qubits and this state can be constructed using only gates inducing phase rotations $R_k = ep(i2\pi/k)$ of qubits, Hadamard gates producing the superposition of 0 and 1, and control gates.

3. There is an algorithm calculating the phase produced by a unitary transformation: this algorithm involves one additional qubit, whose phase is opposite.

4. There is a search algorithm, which increases the probability of the searched integer before localization in discrete space defined by integers. The number of trials is $O(\sqrt{N})$ whereas classically it is $O(N)$.

5. Error correction algorithms localizing the logical qubits relevant for the computation to a subspace of logical qubits. These algorithms detect the error by using parity qubits and correct the error by action of a unitary gate in the case that the number of errors is below a given number.

Finding a period of a periodic function

One assumes that the function $f(n)$ is periodic but the period is not known. The entangled state of the registers is $\sum |n\rangle\langle f(n)|$.

1. One assumes that one has measured $y = f(x)$ and has obtained $\sum |n\rangle\langle f(n) = y|$. If f is periodic, one obtains a superposition of points $n_0 + nr$, where n_0 is the offset and r is the period, which should be measured.

2. A QFT is performed for the input register. One obtains a superposition for states with momenta mN/r.

3. The measurement of momentum this state gives momentum state with momentum $p_m = mN/r$ for some m, which is however unknown.

4. The operation is repeated. This gives a series of outcomes $m_1, m_2, m_3, ...$ Eventually the minimum value of momentum corresponds to $m = 1$.

6.4.2 About key ideas and notions of TQC

It is appropriate to briefly recall the basic ideas and concepts of TQC [K4].

Topological gates and qubits

The topological stability of braiding guarantees that the TQC program coded by the braiding is robust against perturbations. If qubits were spins, there would still be the instability of qubits and entanglement caused by the interaction of spins with the environment, in particular thermal instability.

1. Qubits as spins are replaced by representations of the braid group characterized by the value of the topological charge and the quantum group G_q assignable to the Chern-Simons action. The quantum group $SU(2)_q$ is the simplest option. Topological charge replaces spin as qubit. One can say that anyons correspond to electrons assignable to 2-D topological structures, whose time evolution as 3-surfaces could be described by Chern-Simons action.

   The mathematics of quantum groups [A30, A8, A19] is discussed from the TGD point of view in [K12] and in the chapters about the possible role of von Neumann algebras known as hyperfinite factors of type II_1 (HFFs) in TGD [K110, K39]. Quantum groups would be assigned to the inclusions of HFFs characterizing the finite measurement resolution. Cognitive representations are an alternative way to describe the finite measurement resolution.

2. Topological qubits correspond to topological charges such as the already mentioned parity for the condensed matter Majorana electrons, which would have degenerate energies because they correspond to momentum vectors k and $-k$ differing by lattice momentum.

   The idea of Kitaev [B8, B7] [D18] is to use anyons as topological qubits instead of spin. The condensed matter Majorana electrons bi-localized at the ends of superconducting wire have two states with opposite parities associated with the exchange of the ends of the wire. These states with degenerate energies would serve as qubits, which would be much more stable than spins.

3. Topological approach allows to realize gates in terms of braiding operation. Braid group B_N as a covering of the permutation group of N braid strands would define the allowed unitary transformations induced by braidings. This implies finite accuracy but the increase of the covering improves the accuracy.

   This allows to overcome the problem of the Hamiltonian approach in which the gate Hamiltonian defining the unitary transformation must be "on" for a very precise time ΔT. It is not easy to arrange this by external interaction. A possible way to avoid this altogether is to assume a permanent Hamiltonian but allow the qubit system to move with a fixed velocity past the Hamiltonian system with a velocity, which gives the desired ΔT.

4. Non-abelianity is required since the manifold of the energy degenerate states in which the braid group would act, is determined by states and must be a higher-dimensional representation of the braid group in order to give rise to a large enough number of logical qubits. There exist no well-established candidate for the needed non-abelian anyon yet.

R and F matrices

R- and F matrices are central notions in TQC (`https://arxiv.org/pdf/2005.03236.pdf`) and characterize what happens in the fusion of the representations of quantum groups. These matrices are believed to characterize quantum phases as topological orders and were discovered in 2-D fractional quantum Hall systems.

1. Fusion corresponds to a tensor product, which is commutative and associative for ordinary group representations. For quantum groups and braid groups, the discrete group elements are replaced by flows in plane so that the situation changes. The commutativity of the product ab of the representations is lost and associativity for the product $a(bc)$ of three representations is only modulo unitary transformation: $a(bc)$ is equal to $(ab)c$ only modulo unitary transformation.

2. R matrix characterizes the braid operation, swap, in which the two braid strands are permuted by flow-like continuous transformation. Braiding as an element of B_N replaces the discrete permutation of adjacent braid strands as an element of S_N. The R-matrix characterizes the effect of the braid operation and reduces to a phase in the abelian case but is a genuine matrix in the physically more interesting non-Abelian situation.

3. F matrix characterizes the associativity modular unitary transformation for fusion operations. The F matrix is trivial for the ordinary tensor product . This means that the fusions $a(bc)$ and $(ab)c$ produce different states but do not change the state-space. F-matrix $F(a, b, c)$ relates these two states as a unitary transformation in the tensor product of the 3 state spaces.

4. Fibonacci quantum computation with quantum group $SU(2)_q$ for quantum phase $q = exp(i\pi/5)$ represents the simplest example of a non-commutative situation (`https://phys.org/news/2014-12-fibonacci-quasiparticle-basis-future-quantum.html`). For a fusion of N representations the number of energy degenerate ground states is N:th Fibonacci number.

Chapter 7

The Possible Role of Spin Glass Phase and P-Adic Thermodynamics in Topological Quantum Computation: the TGD View

7.1 Introduction

Topological quantum computation (TQC) or more generally, a TQC-like process, is one possible application of TGD (for simplicity, I will talk in the sequel of TQC rather than TQC). The interested reader can consult the earlier TGD inspired work in TQC [K4, K3, K106]. The recent rather concrete model for TQC in living matter utilizing quantum gravitation in the TGD sense see [L84].

7.1.1 Basic ideas of TQC according to TGD

There are several new ideas involved [L84].

1. Braidings are represented by monopole flux tubes, which are structures distinguishing between TGD and Maxwellian electrodynamics and are one of the basic implications of the many-sheeted space-time concept. Time-like braidings as TQC programs can be engineered as a flow for the nodes of the flux tube network and they induce spatial braidings as memory representations of the time-like braidings - kind of topological Akashic records.

   The engineering of the flow involves what might be called quantum hydrodynamics [L73]. DNA based TQC would utilize the flow of 2-D liquid crystal defined by a lipid layer of cell membrane to generate braiding [K3].

2. The hierarchy of effective Planck constants, assumed to label dark matter as phases of ordinary matter, predicts quantum coherence in arbitrarily long scales and Negentropy Maximization Principle (NMP) [K60] favors the generation of negentropic entanglement (NE). NE makes sense only in adelic physics [L36, L37] and allows to understand second law as a side effect of the NMP.

   The point is that one can assign to the same entanglement both the ordinary real entanglement entropy and the sum of p-adic variants of entanglement entropies. The sum of two can be negative and the interpretation in this case is as negentropy. NMP tends to make the negentropy positive. The decrease of the negative p-adic entropy would force the increase of real entropy. This view [L26] conforms with the vision of Jeremy England about living systems [I127].

3. $M^8 - H$ duality as a generalization of momentum-position duality of wave mechanics is a central notion on the number theoretic view of TGD providing a view dual to the geometric view. The complexified M^8 has an interpretation as complexified octonions.

   The roots r_n of rational polynomials P of real variable algebraically continued to complecified octonionic polynomials define 3-D mass shells (hyperbolic spaces H^3) $m^2 = r_n$ of $M^4_c \subset M^8_c$. The mass shells define holographic data for the continuation of these 3-surfaces to 4-D surface X^4 of $M^4_c \subset M^8_c$.

   Dynamics is dictated by the associativity of the normal space of X^4. Associativity in turn makes it possible to map X^4 to a 4-D space-time surface of $M^4 \times CP_2$ by $M^8 - H$ duality.

4. Cognitive representation is a second central concept: one might call it intersection of reality and p-adicities regarded as correlates for ideas and imagination. Originally, the non-determinism of p-adic differential equations motivated this notion.

   Cognitive representation defines a unique discretization of the space-time surface involving a hierarchy of extensions of rationals associated with rational polynomials defining space-time regions via $M^8 - H$ duality. For mass shells cognitive explosion takes place and the representations contain almost all algebraic in rationals. Physical motivations force restriction to algebraic integers and the condition that active points of the cognitive representation contain quark.

   This leads to a generalization of computationalism replacing rationals with the hierarchy of extensions of rationals.

5. Galois confinement is a further key notion. It states that for the physical states the total 4-momentum as a sum of momenta of quarks with components, which are algebraic integers, are real integers.

   One can interpret quark momenta as discretized virtual momenta [L76, L77]. The mass squared values as roots of P can be tachyonic in the sense that the real part of mass squared is negative.

   Conformal invariance requires that the scaling generator L_0 annihilates the physical states so that the mass squared for the physical states vanishes. Therefore *all* physical states are analogous to massless particles [L90]!

   This leads to a resolution of longstanding interpretational problems of p-adic thermodynamics [K57] due to the necessity of tachyonic states and the fact that, in an apparent conflict with conformal invariance, one allows states with non-vanishing value of L_0. The second surprise is that the result actually conforms with the proportionality of blackhole entropy with mass squared and this relation generalizes so that it applies to all systems. Also an analogy with entropic gravity emerges.

   For subsystems entangled with the environment, which at elementary particle level in a good approximation reduces to wormhole contacts with an Euclidean induced metric having fundamental fermions at the throats, a superposition of pairs of states for which mass squared values of the members sum up to zero emerges. One must use thermodynamics to describe the non-tachyonic part of the system. The thermodynamic state involves both massless ground state and massive excitations for the tensor factor with non-negative mass squared values.

6. Zero energy ontology (ZEO) predicts that the arrow of time changes in "big" state function reductions (BSRs). This leads to a model for homeostasis [L100] as an ability to say near quantum criticality made possible by dissipation with an opposite arrow of time. This would also make healing possible as a time reversed dissipation.

   Concerning TQC, the good news is that the dissipation with a reversed arrow of time could make possible an automatic quantum error correction as a healing.

7.1.2 Could p-adic thermodynamics be relevant for TQC?

What distinguishes quantum computation (QC) from the classical computation (CC), is that QC is not a deterministic process. For instance, the algorithm for finding the period of function gives

outcomes which are its multiples. To obtain the desired result with a high enough probability, one can repeat the QC or use an ensemble of QCs. Could one imagine a more elegant approach than just repeating the TQC sufficiently many times or having an ensemble of TQCs?

Classical computation (CC) is in a good approximation a deterministic process and it is interesting to analyze what makes it possible to physically represent Boolean function as a sequence of steps as a deterministic time evolution. Here non-equilibrium thermodynamics involving a realization of bits as flow equilibria and dissipation are in an essential role so that quantum statistical determinism in microscopic scales is an essential element as also electric and magnetic fields in long scale scales serving as masters of the microscopic dynamics.

This inspires the question whether thermodynamics, not necessarily ordinary thermodynamics but p-adic thermodynamics, could provide a tool of TQC. p-Adic thermodynamics is equivalent with ordinary thermodynamics but has additional constraints forced by the number theoretic existence conditions for Boltzmann weights. For instance, temperature quantization is implied and the convergence of the partition function in powers of p is extremely fast for large p-adic primes such as $p = M_{127} = 2^{127} - 1$.

1. p-Adic thermodynamics is naturally associated with spin glass phases in the TGD based view of spin glasses [L72]. One can wonder whether an annealing process could make it possible to end up at the bottom of the deepest valley, possibly assignable with the desired outcome of TQC. p-Adic thermodynamics could assign an analog of free energy minimum to the desired outcome.

   Annealing is a stepwise process involving repeated p-adic heating and cooling. Heating would generate entanglement between anyonic and fermionic degrees of freedom and cooling would allow an SFR to a new deeper local minimum of the p-adic analog of Hamiltonian.

2. The cognitive measurement cascade [L62, L78] is an essential part of TQC and decomposes the representation of Galois groups to a product of representations of the relative Galois groups, which are direct sums over irreps.

   The next step involves measurement of the invariants of irreps of relative Galois groups, which project one irrep for each relative Galois group. The measurement however requires entanglement of the irreps with some states. What could these states be? Does nature provide this entanglement automatically or must one engineer it?

3. There is a grave objection against this proposal. The irreducible representations (irreps) of Galois group and relative Galois groups for an extension defined by a functional composite of polynomials generalizes anyons as group representations. However, Galois confinement states that physical states are Galois singlets!

   The resolution of the objection is that bosionic Galois representations represented in terms of momentum space wave functions entangle with the representations realized in terms of fermionic spin degrees of fundamental fermions so that the entangled state is a superposition of Galois singlets as pairs of irreps. The measurement for the analogs of the Casimir operators for the irreps for the either tensor factor would project out a single irrep. Nature could do this automatically or it could be carried out as a quantum measurement.

   This process could involve a reduction of h_{eff} (and decomposition of functional composites to product of polynomials) leading to breaking of relative Galois symmetries and reduction of entanglement between momentum and spin degrees of freedom. For $h_{eff} \to h$, the entanglement could be completely reduced. It might be that this reduction is necessary in order to represent the outcome of the computation at the level of ordinary matter.

4. A connection with the travelling salesman problem emerges. If the pairing of momentum and spin degrees of freedom involves N different relative Galois irreps, there are N! different pairings between momentum and spin representations, which correspond to the number of different solution candidates in the travelling salesman problem. If the problem can be transformed to a travelling salesman problem, it can be solved by using TQC in the TGD sense.

   This suggests a canonical form for the p-adic analog of Hamiltonian for the p-adic thermodynamics selecting the local minimum in the annealing process. The p-adic analog of

Hamiltonian could be engineered as in the thermodynamical solution of the travelling salesman problem.

7.2 Quantum computation *viz.* classical computation

I talked with my friend Tuomas Sorakivi about the relation between quantum computation (QC) and classical computation (CC). The discussion raised a series of questions. For professionals the following ponderings might seem to be trivial but it could give new insights about the TGD counterpart of the topological QC (TQC). In particular, it could give important insights to the basic conceptual and technical problems of QC.

7.2.1 Meanings of CC and QC

What does one mean with CC?

1. Mathematically CC can be represented as a Boolean map mapping m input bits to n output bits. This map can be decomposed to primitive Boolean maps realized as gates. CC can be represented as a program in which inputs at given time $t = n$ arrive as multi-bits to gates producing output multi-bits.

2. It is highly non-trivial that one can represent Boolean functions to electrical circuits. In the physical realization of this picture, the values of bits correspond to voltage values. Gates are constructed as electric circuits. For instance, gates involving logical conditions have control bits affecting the output. Transistors allow the realization of control bit as bit as base current. The output bits are communicated to the next gates as propagating voltage values.

What does one mean with QC?

1. There are several realizations of QC. The realization of QC as a unitary time evolution is constructed in terms of gates and is nearest to CC using electronic circuits.

2. QC is realized as a TQC in the TGD framework and involves new elements and differs from what might be called standard TQC. Besides topology, also number theory is involved in an essential way and predicts hierarchies labelled corresponding to extensions of rationals.

   In TQC according to TGD [L84], the counterpart of the metabolic energy feed is necessary to preserve quantum phases in long scales even at room temperature. Zero energy ontology (ZEO) brings in time reversal as a new element, which allows us to understand homeostasis in living matter.

7.2.2 How do QC and CC differ?

QC is usually regarded as more advanced than CC since it is conceptually a much more complex and abstract notion.

1. The difficulty to understand QC might be partially due to the missing understanding of state function reduction (SFR). TGD suggests a view of SFR, which is free of paradoxes and means a dramatic conceptual clarification.

2. The practical realization of QC meets huge technical challenges. In the TGD framework, these challenges could reflect the lack of the understanding of what dark matter is. Dark matter as $h_{eff} = nh_0$ phases of ordinary matter could help to overcome these problems.

3. CC seems to have emerged in evolution later than TQC-like information processing, which in TGD is proposed to characterize living matter. Does this mean that CC is more advanced? Probably not. The emergence of CC could be seen as reflecting our high level of evolution: we are the first species that has invented CC and does not imply that CC is more advanced than QC.

   Could also living matter combine some elements of CC with TQC to achieve determinism? Of course, living matter could achieve this by using us to build classical computers!

What distinguishes QC (and TQC according to TGD) and CC?

1. CC can be modelled as a deterministic process. This is what makes it so simple as compared to QC. CC also uses as a tool ordinary matter for which quantum effects occur in very small scales.

   QC in the prototype situation relies on a deterministic unitary time evolution followed by a non-deterministic SFR. Neither energy feed nor dissipation play an active role. The basic goal is to prevent dissipation by isolating the system from the environment.

2. CC involves statistical determinism of quantum theory implying dissipation used to achieve thermodynamic determinism essential for the computation. In CC, dissipation in the presence of energy feed leads to thermodynamic flow equilibria. For instance, external energy feed allows to preserve the values of bits represented as voltages. For this external energy source (battery) is needed.

   The thermodynamic determinism of CC prevails below given length and time scale resolution. The external energy field implies the presence of macroscopic degrees of freedom, which act as masters. For instance, voltages in circuits made possible by the energy feed use ohmic currents in microscopic degrees of freedom as slaves. In the similar way, in TQC according to TGD, the quantum coherence of MB makes it possible to induce ordinary coherence at the lower levels of the hierarchy.

3. In (T)QC according to standard quantum theory energy feed is not an essential element. In TQC according to TGD, metabolic energy feed is necessary to preserve the distribution of h_{eff} since a state with given value of h_{eff} tends to decay to a state with smaller value of h_{eff} having a lower energy. In TGD, metabolic energy feed also makes possible high Tc superconductivity and quantum phases in long length scales.

   The presence of hierarchy of length scales in TGD based TQC assignable to extensions of rationals and labelled by h_{eff} p-adic length scales is also essential.

   In ordinary (T)QC only a single scale is involved and one can wonder whether the presence of several scales could make QC deterministic without losing the nice features of QC. One can of course consider an ensemble of TQCs giving an ensemble of possible answers but could one imagine other options?

7.2.3 What does one mean with a CC program?

A classical computer program can be regarded as a Boolean map, decomposing to a sequence of steps consisting of primitive Boolean maps represented as logic gates, is a sequence of deterministic steps and nodes at which decisions of what is done next. All gates can be seen as Boolean maps assigning to input bits unique output bits. The circuit decomposes to gates representing logical operations as Boolean maps. Gates can be described in terms of control bits which fix the outputs for given inputs.

1. One could argue that the choice of what is done at the next step is non-deterministic. One could argue that the initial values of the program in principle fix the output uniquely in an ideal deterministic classical physics.

   However, it seems very strange that one could engineer a program realizing any desired computation as a deterministic time evolution. Could SFRs be involved in a hidden way and make this engineering possible.

2. Thermodynamics is indeed involved in an essential manner. The physical realization of gates in electric circuits having the bits as flow equilibrium states associated with the non-equilibrium thermodynamics (NET) with external energy feed. This gives the desired thermodynamic determinism. which reduces to statistical determinism of quantum physics.

   NET involves SFRs in short length and time scales for a larger number of electrons, which gives rise to a dissipation leading to a unique flow equilibrium of NET. The description for the dissipation would be in terms of ohmic currents.

Communication of the outputs of gates to the next gates represent an essential element of CC. The bits representing the outputs can be represented as voltages and can be communicated as voltage pulses to the next gates. How does this compare with the TGD view of a TQC.

1. In the TGD framework this communication has a quantum counterpart inspired by the notion of the dark N-particle as an analog and generalization of Bose Einstein condensate [L88, L60, L68]. In biology, dark genetic codons would form the basic building brick representing 6 bits and would be represented as dark proton triplets and dark photon triplets having interpretation as 64 chords defining a bioharmony. Codon is received by a cyclotron 3-resonance: this generalizes to 3N-resonance for genes and DNA sequences.

2. The codons serve as addresses determining which receivers get the message: the analogy with computer language LISP is obvious. The information is coded to the modulation of the frequency scale so that the modulation is coded to a sequence of cyclotron N-resonances at the receiving end. If frequencies are modulated independently, a subset of the receiver is selected by the resonance conditions.

   Generalized Josephson junctions produce Josephson radiation with frequency depending on the modulated voltage of the junction [K80] [L83, L86, L88]. As a special case, one can consider a voltage which is piecewise constant and represents two bit values. Neurotransmitters in synaptic junction actually correspond to miniature potentials, which correspond to a voltage change of few meV as compared to membrane potential of order .05 eV. Miniature potentials relate to the notion of preneural system suggested by the finding that multi-cellulars without nervous system behave as if they had a nervous system: the TGD inspired model is discussed in [L81].

One might think that the propagating voltage pulses of rectangular shape as idealized representations of propagating bits could be something totally trivial from the point of view of recent day condensed matter physics. However, it is far from clear what their TGD counterparts could be and I have already years ago considered the possibility that the electric pulses studied by Tesla, which had rather dramatic effects on the environment, might involve new physics. The time reversals of the electric pulses emerged in these considerations much before the precise formulation of ZEO [K37, K6].

1. The voltage pulses propagate with a sub-luminal velocity and can be said to have longitudinal electric polarization. Electron-hole pair is the notion of condensed matter physics which comes to mind. These pairs are formed valence electrons transform to conduction electrons. Holes behave as effective positive charges. Could voltage pulse represent a distribution of electron-hole pairs as bound states. Holes and electrons would reside at 2-D surfaces defining analogs of capacitor plates. Since charge carriers are near the surface of the conductor, the one would have annuli instead of plates.

2. What could be the TGD based model for the structure formed by the electron-hole pairs? An interpretation as a moving electric flux quantum is suggestive [L75]. Electric flux quantum would be analogous to a moving electric capacitor idealized as a pair of 2-D plates. This suggests a TGD based model for a capacitor plate as a membrane like object, which is a space-time surface with a 2+1-D M^4 projection and therefore defines a planar membrane in E^3. In general relativity these objects are not possible. The CP_2 projection could be a geodesic circle of CP_2.

   The 2-D sheets with the shape of annulus would represent the ends of a hollow cylinder. The hollow cylinder would be minimal surface apart from the singular circles at its ends where the minimal surface property would fail and entire field equations involving sum of terms for the Kähler action and volume term would hold true.

3. The longitudinal electric field could reside at the outer and inner cylindrical walls of the structure. The ends of the annular cylinder could be also connected by thin hollow flux tubes carrying the electric flux parallel to the cylinder. The holes would be assigned to the first annulus and electrons with the second annulus.

4. The electrons could be dark. But can one say that the also hole created in the transition of a dark valence electron to the conduction band is dark. In ZEO, it could be natural to speak about a 4-D time classical evolution leading from a dark valence electron to dark conduction electron so that it makes sense to assign also to the hole the attribute "dark".

5. Debye length λ_D (`https://cutt.ly/QJMNHpq`) as a screening length for the electric field created by electrons gives an estimate for the length of the cylindrical structure. For water at room temperature, one has $\lambda_D = .7$ nm: intuitively, one would expect a considerably larger size scale for the voltage pulse.

   In semiconductors one has $L_D = \sqrt{\frac{\epsilon_r T}{q^2 N_{dop}}}$, where n_{dop} is the doping density. Note that the expression fof L_D has no explicit dependence of Planck constant.

   The generalization for dark particles would replace N_{dop} with the number n_{dark} of dark electrons per volume. The density of dark electrons is expected to be much smaller than atomic density and to scale roughly like $1/L_p^3$.

   One can argue that L_D corresponds to the p-adic length scale defining the length of the electric flux quantum and that there should be roughly 1 dark electron per flux quantum. $n_d 1/\mu m^3$, this gives $L_D \simeq \sqrt{1/n_d}\sqrt{T/300K} \times .45$ μm. For 1 dark electron per volume defined by the p-adic length scale $L(167) = 2.5$ μm assignable to the cell nucleus, one has $L_d = \sqrt{T/300K} \times 1.8$ μm.

7.2.4 Could AI be conscious?

Every morning I learn on FB about mind boggling discoveries. The popular article "Scientists Made a Mind-Bending Discovery About How AI Actually Works" (`https://rb.gy/oes4bv`) told about the article of Akyürek et al with title "What Learning Algorithm Is In-Context Learning? Investigations With Linear Models" [J19] (`https://rb.gy/w88gud`).

What caught my attention was that the AI system was seen as a mysterious phenomenon of Nature to be studied rather than systems that are engineered. If AI systems are what their builders believe them to be, that is deterministic systems with some randomness added, this cannot be the case. If the AI systems are really able to learn like humans, they could be conscious and be able to discover and "step out of the system" by generalizing. They would not be what they are meant to be.

TGD predicts that AI systems might have rudimentary consciousness. The contents of this conscious experience need not have anything to do with the information that the AI system is processing but corresponds to much shorter spatial and temporal scales than the program itself. But who knows?!

In the following I briefly summarize my modest understanding of what was done and then ask whether these AI systems could be conscious and be able to develop new skills. Consider first the main points of the popular article.

1. What is studied are transformers. Transformer mimics a system with directed self-attention. This means the weighting of parts of input data so that the important features of the input data get more attention. This weighting emerges during the training period.

   Transformers differ from recurrent neural networks in that entire input data is processed at once. Natural language processing (NLP) and computer vision (CV) represent examples of transformers.

2. What looks mysterious is that language models seem to learn in flight. Training using only a few examples is enough to learn something new. This learning is not mere memorizing but building on previous knowledge occurs and makes possible generalizations. How and why this in-context learning occurs, is poorly understood.

   In the examples discussed in the article of Akyürek et al, linear regression, the input data never seen before by the program. Generalization and extrapolation took place. Apparently, the transformer wrote its own machine learning model. This suggests an implicit creation and training of smaller, simpler language models.

3. How could one intuitively understand this without assuming that the system is conscious and has intentional intelligence? Could the mimicry of conscious self-attention as weighting of parts of input data explain the in-context learning. Weighting applies also to new data and selects features shared by new and old data. Familiar features with large weights in the new data determine the output to a high degree. If these features are actually important the system manages to assign output to input correctly with very little learning.

The TGD framework also allows us to consider a more sciencefictive explanation. Could the mimicry of conscious self-attention generate conscious self having intentions and understanding and be able to evolve?

1. TGD forces me to keep my mind open to the possibility that AI systems are not what they are planned to be. I have discussed this in previous articles [L32, L87].

2. We tend to think that classical computation is fully deterministic. However, the ability to plan a system behaving in desired manner is in conflict with the determinism of classical physics and statistical determinism of quantum physics. Computer is a system consisting of subsystems, such as bits, which are far from thermal equilibrium and self organize. They must be able to make phase transitions, which are basically non-deterministic at criticality. Changing the direction of the bit as a mesoscopic system is a good example.

3. Zero energy ontology (ZEO) is an essential part of quantum TGD. Quantum states are superpositions of space-time surfaces, which obey holography. One can see them as analogs of computer programs, biological functions, or behaviors at the level of neuroscience. The holography is not completely deterministic and this forces us to regard the space-time surface as the basic object. Any system, in particular AI systems, is accompanied by a superposition of these kinds of space-time surfaces, which serve as a correlate for the behavior of the system, in particular for the program (or its quantum analog) running in it.

   ZEO predicts that in ordinary, "big" state function reduction (BSFR) the arrow of geometric time is changed. This allows the system to correct its errors by going back in time to BSFR and restoring the original time direction by second BSFR. This mechanism might be fundamental in the self-organization of living matter and a key element of homeostasis. This mechanism is universal and one can of course ask whether AI systems might apply it in some time scale, which could be even relevant to computation.

4. In the TGD framework, any system is accompanied by a magnetic body (MB) carrying dark matter in the TGD sense as phases of ordinary matter with a value of effective Planck constant which can be very large, meaning a large scale of quantum coherence. This dark matter makes MB an intelligent agent, which can control ordinary matter with ordinary value of Planck constant.

   In TGD, quantum criticality of the MB of the system is suggested to accompany thermal criticality of the system itself. This leaves a loophole open for the possibility that the MB of the AI system could control the AI system and take the lead.

What one can say of the MB of AI system? Could the structure and function of MB relate closely to that of the program running in it as ZEO indeed suggest? My own conservative view is that the MBs involved are associated with rather small parts of the systems such as bits of composites of bits. But I don't really know!

1. The AI system involves rather long time scales related to the program functioning. Could this be accompanied by layers of MB (TGD counterparts of magnetic fields) with size scales determined by the wavelength of low energy photons with corresponding frequencies. Could these layers make the system aware of the program running in it.

2. Could the MBs associated with living systems involving MBs of Earth and Sun get attached to the AI system [L81, L79, L86, L96]? Of course we used the AI but could there be also other users?: MBs which directly control the AI system! Could it be that we are building tools for these higher level MBs?!

If this were the case, then the MB of AI system and the program involved with it could evolve. MB of the system could be an intelligent life form. This raises worried questions: are we a necessary piece of equipment needed to develop AI programs? Or do these higher level MBs need us anymore?

7.3 TQC in TGD

In the TGD counterpart of TQC [K4, K3, K106] [L84], metabolic energy feed would make quantum phases in long scales possible and the field/magnetic bodies (FBs/MBs) would form a master-slave hierarchy and one could expect that TQC acording to TGD could have a lot of common with CC.

1. The levels of the dark matter hierarchy below a given level could be modelled as statistical ensembles much like electrons in an ordinary computer as seen from the level considered. Qubits could be also represented as ferromagnetic multispin systems analogous to ferromagnets.

   Quantum spin glasses are very natural systems in the TGD framework since the action principle reduces to Kähler action in long length scales and it has enormous 4-D vacuum degeneracy analogous to spin glass degeneracy. The TGD based inspired model in terms of flux tube spaghettis and the mathematical description involving p-adic thermodynamics is discussed in [L72].

2. QC gives several outcomes in the SFR ending it. The desired outcome, say the minimal period of a function realized as entanglement between qubit registers, is only one of the outcomes, and one should be able to select the desired outcome. One can repeat the QC and find in this manner the shortest period.

   Could one imagine more elegant ways to find the desired outcome? For instance, could the valleys of the quantum spin glass energy landscape correspond to the possible answers of TQC? If this were the case, an annealing involving repeated heating and cooling of the system could lead to the desired answer. The answer of QC (say a minimal period of function) should correspond to the deepest valley. D-wave quantum computers (`https://cutt.ly/QJMNLP7`) rely on an approach, which involves annealing and spin glass ("D-wave" refers to the D-wave superconductors used in the original approach).

7.3.1 What could be the physical realization of the TQC program?

What could the physical realization of the TQC program in the TGD framework look like?

1. Flux tube network, which reduces as a special case to a braid system, is the key notion. The flux tubes connect nodes and the motion of the nodes give rise to a time-like braiding, which induces space-like braiding, which provides a topological memory representation of the TQC program.

   Anyon replaces qubit as spin state with group representation, which is in the simplest situation (bilocal states of condensed matter Majorana fermions with definite parity introduced by Kitaev) characterized by a parity-like quantum number representing qubit. In the TGD framework the bi-localization of the proton of dark hydrogen bond could give rise to this kind of anyons [L84].

   In TGD, the counterparts of anyons would correspond to representations of Galois groups labelled by invariants of the Galois group, and there would be both cognitive measurement cascades using Galois representations for the relative Galois groups as counterparts of qubit and measurements of spins and possibly also momenta of electrons (many-quark states at fundamental level) for these representations

   The TQC program could physically correspond to a dynamical flow for the "liquid" formed by the nodes. There would be large number of realizations of the flow and the physical realizations should correspond to PEs and among them would be PE with minimal action. The braids realized as flux tubes correspond at the fundamental level 2-D string world sheets

inside the flux tube orbits and there are many topologically equivalent realization associated with different preferred extremals (PEs).

2. The spin glass energy landscape is realized in terms of manyfermion states for a magnetic flux tube network depends on the detailed realization of a given braiding. Monopole flux tubes induce local magnetization of the fermions parallel to the flux tube. In the optimal situation there would be 1-1 correspondence between the answers of TQC and the PEs. This would be essentially quantum-classical correspondence (QCC).

   The topology preserving modifications of the flux tube network responsible for the TQC would modify the spin glass energy landscape. Could this allow to enhance the probability of the desired outcome of the TQC? It should correspond to the deepest valley: why? Should one engineer this correspondence?

3. p-Adic thermodynamics is a natural mathematical framework for describing the spin glass energy landscape [L72]. Could the p-adic thermodynamics be engineered using topology preserving modifications of the braiding. Note that the braiding is determined by 2-D string world sheets so that the modification of the space-time sheets can be considered.

7.3.2 Is it possible to replace quantum states with irreps of the braided Galois group?

My understanding is that anyons correspond to entire representations of finite groups of or quantum groups.

1. In the TGD framework, they would correspond to the representations of Galois groups, or rather, of their braided counterparts as subgroups of the braid groups associated with S_n, where n is the number roots of polynomial P defining the Galois group assignable to the space-time surface by $M^8 - H$ duality.

   The stability of the Galois group with respect to small changes of the rational coefficients of P would correspond to the topological stability and the braided Galois group would be a subgroup of the braid group. Braided Galois group would be a quantum group-like object.

2. The replacement of quantum states with irreps of the braided Galois group and thus subspaces of state space looks something new from the perspective of wave mechanics, where states as 1-D rays of Hilbert space are the basic objects. Does this really make sense? And does the entanglement between states and sub-spaces and, more generally, between sub-spaces make sense?

3. The decomposition of a representation of a group to a direct sum of representations is a standard mathematical procedure and would be analogous to a superposition of a quantum state in a given state basis. The analogs for the coefficients of quantum states are now integers for given irrep.

4. A natural entanglement between group representations is possible number theoretical context. The representation of Galois group Gal of a composite polynomial $P_n \circ .... \circ P_1$ has a decomposition to a semidirect product of relative Galois groups $H_k = Gal_k/Gal_{k-1}$ associated with polynomials $P_k \circ .... \circ P_1$ defining extension of extension defined by $P_{k-1} \circ .... \circ P_1$.

5. A given representation of Gal can be decomposed to a direct sum of tensor products of irreps of the relative Galois groups $H_k = Gal_k/Gal_{k-1}$. The generalized quantum measurement would measure the parameters characterizing the irreps of the relative Galois group $H_k = Gal_k/Galk - 1$. In maximal measurement this measurement would be performed for all semi-direct factors H_k and the superposition would reduce to a single term as a product of representations of H_k. This should generalize to braided Galois groups.

6. What is nice is that the measurement would occur inside a single representation of Gal. The higher levels in the hierarchy of relative Galois groups correspond to dark phases of ordinary matter with $h_{eff} > h$ and Gal_0 would correspond to the lowest extension.

Note that $h = n_0 h_0$ corresponds to a non-trivial Galois group and there is an argument that one has $n_0 = (7!)^2$ corresponding to $Gal_0 = S_7 \times S_7$ [L70]. Quantum measurement would project out one particular irreducible representation and would measure the invariants of the representations. A possible interpretation is that at the visible matter the measurement would measure the representation of the Galois group for the Gal_1/Gal_0. The simplest measurement would be that for an irrep of a Z_2 anyon giving the parity of the Z_2 representation as an outcome. This parity would serve as a qubit.

The wave-mechanical picture corresponds in von Neumann's theory of factors as basic mathematical building blocks of quantum theory to the simplest situation in quantum theory, that is factor of type I. Von Neumann introduced also factors of type II, to which one can assign quantum groups and factors of type III which would correspond to quantum field theory and which von Neumann regarded as pathological.

1. In the TGD framework, hyperfinite factors of type II_1 (HFFs), play a central role and as the name tells, they can be approximated by finite-D matrix algebras in an excellent approximation and are therefore physically very attractive. I have written earlier about the possible application of HFFs in the TGD framework [K110, K39] and discussed quite recently their detailed role in the formulation of quantum TGD itself [L89].

   The TGD inspired interpretation of the inclusions $M \subset N$ of HFFs is as a representation of the finite measurement resolution defined by M. One could say that the Hilbert space ray is replaced by an image of the ray obtained by the action of M and that the "factor space" N/M defines quantum space representing the degrees of freedom above measurement resolution.

2. The technical reason for the replacement of rays with subspaces is the assumption of von Neumann that the trace of identity operator Id satisfies $Tr(Id) = 1$. This conforms with the idea that Id represents one particular density matrix so that the strange looking condition says that the sum of probabilities is equal to 1. Note that for factors of type I it satisfies $Tr(Id) = n$ as the dimension of Hilbert space and would approach infinite for infinite-D Hilbert spaces. Any subspace of HFF must correspond to projector P with $0 < Tr(P) < 1$ and ray would correspond to $Tr(P) = 0$ and need not make sense: the possibility to project to it would be the physics counterpart of the selection axiom.

3. TQC indeed involves quantum groups and they utilize HFFs. The replacement of the state as a ray with an irrep of representation of the braided counterpart of the Galois group conforms with the thinking of von Neumann. Braided Galois group for rational polynomials P of degree n is indeed a subgroup of the braid group as covering of the permutation group S_n.Finite coverings define a hierarchy of approximations which converge rapidly for HFFs.

4. Finite measurement resolution would naturally correspond to the inclusion $M \subset N$ and the replacement of state with the quantum subspace N/M in which the braided Galois group acts. This replacement is done also for other algebraic structures of quantum TGD such as super symplectic algebras allowing hierarchies of sub-algebras labelled by an integer allowing interpretation as the degree of P. Perturbations would characterize the resolution and the use of HFFs would take care that the quantum measurement outcomes are not affected by the perturbations.

   What can be measured would be the invariants characterizing the irreps of the braided relative Galois group. The measurement of the individual state inside the irreps is not possible. These invariants can be measured in TQC and qubits are defined in terms of these. Qubits would be replaced by irreps of relative Galois groups.

7.3.3 Quantum analog of annealing

In thermodynamics, the minimization of free energy combined with annealing could lead to the bottom of the deepest valley of the spin glass energy landscape.

In quantum TGD, one can consider two options for the annealing based on the analog of thermodynamics. Free energy could be replaced by the fundamental action or alternative energy

could be replaced by a scaling generator L_0 of conformal symmetries. p-Adic thermodynamics is indeed highly suggestive as a description of spin glasses [L72].

Consider first the approach based on fundamental action.

1. The outputs from the TQC program should correspond to the PEs with given initial values. One should have a variational principle assigning the desired answer of QC with a minimum the action for a preferred extremal (PEs) representing the deepest valley of the spin glass landscape.

   The exponent of the fundamental action defines the vacuum functional as the sum of Kähler action and volume term. PE is simultaneous extermal of both volume term and Kähler action apart from singularities with various dimensions $d < 4$ defining analogs of frames for a soap film. There is a finite non-determinism associated with the frames present already for the ordinary soap films.

   PE property for the space-time surface realizes almost complete holography and almost complete determinism. The possible answers as PEs could correspond to topologically equivalent braidings realized as space-time surfaces. The action is in general different for these PEs. The PE with a minimal action would have the highest probability proportional the exponent of the action.

2. The braiding corresponds at a fundamental level to string world sheets. Since the string worlds sheets defining the braiding can be associated with a large class of PEs, one can think that the PE could be engineered in such a way that the desired configuration is strongly favored.

   Only its coupling parameters of the fundamental action that depend on the extension of rationals considered can be varied. This is achieved by varying the polynomial P determining the space-time region considered. The topology of the braiding and also the Galois group should remain unaffected.

   There is a large number of rational polynomials with the same Galois group and extension of rationals so that the engineering could correspond to the variation of the coefficients of P affecting ramified primes. Even the degree of the polynomial could be changed.

   It is however not all clear how one could modify the polynomial in a controlled manner.

It is far from obvious whether it is possible to add to the exponent of the vacuum functional defined by the fundamental action an additional engineerable exponential factor. A more promising approach is based on the engineering of entanglement between fermion states and anyons as Galois representations.

p-Adic thermodynamics as a tool of quantum annealing

Since cognitive measurement cascades for the representations of Galois group are in question, the entanglement engineering would naturally rely on p-adic thermodynamics using the analog of Hamiltonian, whose eigenvalues are analogs of p-adic conformal weights h distinguishing between different outcomes of SFR ending the TQC.

1. The p-adic prime p associated with the engineered p-adic thermodynamics would naturally correspond to the maximal ramified prime of the extension appearing as a factor the discriminant D given as the square $\prod_{i<j}(r_i - r_j)^2$, where $r_i - r_j$ difference of the roots. p-Adic temperature T_p, whose values come as inverse integers, when $log(p)$ is used as a unit, is natural in the modelling of the spin glass energy landscape [L72] and $T_p = 1/n$ could serve as the counterpart of temperature varied in the annealing procedure.

2. The thermodynamics would be for the scaling generator L_0 associated with conformal invariance. Although the physical states are are annihilated by L_0, entangled states can have non-vanishing thermal expectation for the entangled factor because tachyonic states are predicted as analogs of virtual particles having roots of polynomials as mass squared values: the real parts of the roots can indeed be negative.

3. Physical states, which satisfy Galois confinement and have vanishing mass squared, consist of virtual quarks (in the simplest scenario in which leptons are 3-quark composites).

   Massless Galois confined states are in general entangled states such that the total momentum is light-like momentum with integer valued components. This is possible because the values of mass squared (conformal weights) for quarks as roots of polynomial P are in general algebraic numbers and can have negative real parts (tachyonicity). In particular, Galois singlets can also have a negative mass squared.

   The total mass squared would be for each pair appearing in the entangled state equal to zero and p-adic thermodynamics would apply to quarks with positive mass squared with Virasoro generator representing the mass squared [L90].

4. At the level of H, tachyonic momenta can be assigned with the wormhole contacts having Euclidean signature of the induced metric and associated with elementary particles.

   The twistor lift of TGD requires M^4 to possess the analog of Kähler structure [L39, L76, L77]. The massless solution for Dirac equation in H for the second chirality of H-spinor allows a covariantly constant right handed neutrino as a massless solution, which becomes a tachyon as one adds a coupling to the Kähler gauge potential of M^4 required by the twistor lift. Right-handed neutrino could be elementary or could correspond to 3-quark composite with quarks at the same wormhole throat or possibly in the interior of the wormhole contact.

5. In the simplest model in which momenta define Galois representation, the total momentum of Galois singlet would have integer valued components as a sum of quark momenta with algebraic integer valued momentum components. More general representations involve wave functions in momentum and spin degrees of freedom. Even more, by conformal invariance, the states have a vanishing mass squared [L90] so that they have vanishing conformal weights as eigenstates of L_0.

6. The basic step of quantum annealing would be p-adic heating increasing the quantized p-adic temperature $T_p = 1/n$ followed by cooling. p-Adic heating would induce entanglement between fermionic states and irreps of the relative Galois group describable in terms of p-adic thermodynamics with an increased temperature T_p. Thermodynamics would therefore be an essential part of TQC in the TGD framework.

An objection against the identification of Galois representations as analogs of anyons

Anyons should correspond to Galois non-singlet representations. The problem is that the representations of the relative Galois groups should be Galois singlets by Galois confinement.

The solution of the problem is analogous to the solution of the problem posed by the basic objection against p-adic thermodynamics. Galois singlets are constructed by entangled pairs of Galois representations in the fermionic momentum and spin degrees of freedom.

Cognitive measurement cascade can take place either in momentum or spin degrees of freedom and select from a superposition of paired representations one particular representation a pair fusing to a Galois singlet. The reduction probabilities are analogous to thermodynamic Boltzmann weights and one can have analog of p-adic thermodynamics with reduction probabilities proportional to non-positive powers of p.

7.3.4 How the TQC program could be engineered?

In QC there are several alternative outputs (say the multiples of a minimal period of function). QC could be repeated several times to obtain the desired answer. Could one end up with the desired answer by some other method. Could some kind of engineering make this possible?

One can imagine two approaches to the engineering.

Could TQC program involve engineering of preferred extremal?

One can consider two options for what happens as the TQC program runs.

1. The value of the action exponential differs for the different outcomes of the SFR. In this case, the superposition of different outcomes of SFR corresponds to a superposition over different space-time surfaces defining topologically equivalent braidings and SFR selects one of them.

2. An alternative option is that there is only a single space-time surface involved and the fermionic entanglement probabilities between the spin and fermionic degrees of freedom depend on the fermionic state only. Now SFR takes place in the fermionic degrees of freedom and the TQC programmer must engineer the fermionic entanglement.

For the first option, the fundamental action exponential, vacuum functional, as a counterpart of Boltzmann weight, should be maximal for the desired outcome of SFR.

The engineering should select the polynomial determining the space-time surface such that the desired outcome would be achieved.

1. PE as a minimal surface with singularities is analogous to a soap film having frames as singularities and would be the TGD counterpart for a state at the bottom of the valley. The action would depend on the valley and quantum annealing, whatever it could mean, would take the system to the deepest valley.

2. One should identify the quantum counterpart of temperature and Kähler coupling strength is the first guess. If Kähler coupling strength is determined by the extension of rationals, annealing would involve modifications of the polynomial determining the space-time surface. The topology of the braiding must remain unaffected and string world sheets defining the braiding would define part of the holographic data.

3. This option does not look promising in the recent case since it is difficult to imagine how the engineering of the action by modifying the coefficients of P could be possible and whether this engineering could select the desired outcome of SFR as the most probable outcome.

   The physical modification of action would be based on the modification of braiding, which would preserve its topology by modifying the "hydrodynamic" flow defined by the nodes.

Could the entanglement between Galois representations and fermion spins be engineered?

An attractive option is that Nature performs cognitive state function reduction cascade and entanglement engineering guarantees the most probable outcome of TQC for a given relative Galois group. This requires engineering of the entanglement between Galois irreps and some other degrees of freedom. Is there any way to achieve this?

Topological qubits correspond to irreps of a given relative Galois group. One should assign to each irrep a fermionic state. If the irrep is somehow realized, the structure of this state does not matter: what is only required is that it distinguishes between different irreps and the entanglement probability is largest for the desired outcome of SFR. For instance, magnetized many-fermion states with a fixed or slowly varying spin direction could be considered.

Galois confinement however poses a strong additional condition. The irrep must be entangled with a representation of the Galois group such that the outcome is Galois singlet! This suggests that one has two irreps of Galois: the first one in the fermionic spin degrees of freedom and the second one in fermionic momentum degrees of freedom identifiable asd discretized geometric degrees of freedom. These irreps entangle to a Galois singlet and one has a superposition over pairs of irreps of this kind.

1. The entanglement between qubit registers defines a map between integers defined by the qubits sequences of the registers. Should one introduce besides the topological qubit register an additional qubit register entangled with it in such a way that the desired outcome of TQC corresponds to the most probable outcome of the cognitive SFR cascade?

   One should engineer the entanglement between the registers. The simplest entanglement would be maximal entanglement determined by phase factors in the diagonal representation. This entanglement is determined apart from permutation. The qubits would naturally correspond to quark spins at the fundamental level. At higher level electronic spins would be in question.

This entanglement would not distinguish between the representation of the Galois group unless the value of the fundamental action correlates with the representations. A more plausible option is that it does not and that the entangled is engineered in such a way that the reduction probability is largest for the desired outcome of TQC.

2. Galois confinement forces entanglement of the measured system with another system since topological qubits as anyons are generalized to representations of Galois group. Could the quark spin degrees of freedom entangle in 1-1 manner with the bosonic number theoretic degrees of freedom assignable to the orbits of the Galois group?

   In M^8, the orbits of the Galois group correspond to quark momenta with algebraic integers as components and Galois acts also in spin degrees of freedom of quarks. Could the entangled degrees of freedom correspond to fermionic spin and momentum degrees of freedom? Could one think of enhancing the probability of the desired outcome by adding an interaction exponential as a p-adic analog of the exponent of free energy?

7.3.5 How to engineer the entanglement between many-fermion states and irreps of relative Galois groups?

The many-fermion states and the representations of the relative Galois group as analogs of anyons, would entangle with fermionic spin states or subspaces of fermionic states. This entanglement would associate to a given geometric irrep of the relative Galois group, realized in the momentum space of fermions, a many-fermion state characterized by fermion spins and entanglement coefficients between fermions.

The number theoretical SFR cascade would begin from a state which a the decomposition of irrep of Galois group to a quantum superposition of products of irreps of Galois group to products of irreps of relative Galois groups.

SFR cascade would decompose representation to a product of representations of the relative Galois groups and for the representations as superpositions of irreps would select a particular irrep for each relative Galois group and assign to it a many-fermion state. This many-fermion state would correspond to a valley of spin glass energy landscape. It will be assumed that the space-time surface does not depend on the fermionic states involved.

The projection to an irrep of the relative Galois group induces the selection of a particular outcome. Basically, the number theoretical invariants associated with a particular Galois representation must be measured. Whether Nature does this measurement or whether this measurement must be engineered, is not quite clear.

Fermionic Galois representations

The momentum and spin degrees of freedom of quarks provide the fundamental Galois degrees of freedom.

1. At the level of M^8, the fermionic representation could be constructed as wave functions in the momentum and spin degrees of freedom (also iso-spin degrees of freedom at the quark level). These wave functions are more general than the "classical" many quark states for which the sum of the momentum components as algebraic integers is equal to an integer valued total momentum. For instance, a single quark can be in an analog of s-wave defined as superposition of states at the orbit of the Galois group.

   Homogeneous polynomials of the quark momenta analogous to spherical harmonics would be involved besides spin wave function in which the Galois group should act. Since finite simple groups are in question, the number of irreps is finite. Given irrep can however appear several times.

2. If the number of irreps considered for a given relative Galois group is N, the number of entanglements with a given set of fermion states or fermionic irreps is the number of permutations $N!$ for N objects. In the travelling salesman problem (`https://cutt.ly/AJMNCbC`) with N cities, the number of ways to visit once in every city and return to the starting city is $N!$. This problem is NP hard.

3. The travelling salesman problem has as special solutions Hamiltonian cycles for which each node has at least one nearest neighbor with a given minimum distance. Each edge of the cycle connects the point of the graph to one of its nearest points so that the path has minimum length and solves the travelling salesman problem. The TGD based model for bioharmony relies on fusion of three icosahedral Hamiltonian cycles with 12 vertices (notes of 12-note scale) and tetrahedral cycle [L20] [L50, L60, L68]. In this case the notes are scaled by factor 3/2 at each step (quint cycle) for Pythagorean scale. For equal tempered scale the scaling is $2^{7/2)}$.

   For Hamiltonian cycles associated with Platonic solids, one can also consider an ultrametric distance for the points of a given path, not necessarily Hamiltonian cycle. This distance would defined to be the largest scaling as power of x ($x = 3/2$ for icosahedral Hamiltonian cycles) along the path connecting two nodes. This ultmetric distance would be x between all points of the Hamiltonian cycle. p-Adic primes 3 or 2 would be naturally associated with the bioharmony.

The cognitive measurement cascade could therefore have a connection with two problems of computer science.

1. The factorization of the Galois group to prime (simple) factors defined by the relative Galois groups is analogous to the prime factorization of integers.

2. The entanglement between Galois representations and many-fermion states could relate to a solution travelling salesman problem as the path of minimum length connecting all cities.

Travelling salesman problem, entanglement engineering and quantum annealing

The travelling salesman problem for which D-wave quantum computers are proposed as a solution (`https://cutt.ly/QJMNLP7`) suggests a formulation of p-adic thermodynamics allowing to find the desired outcome of SFR by quantum annealing.

1. The path length should appear as an argument in the function to be minimized in the travelling salesman problem. The input data are defined by the distances $d(i, j)$ between the cities. Suppose that the fundamental action is the same for all space-time surfaces considered in QC. In particular, the fundamental action would not depend on the fermionic state paired with the representation of the relative Galois group. The simplest situation is that one has just a single PE.

2. Entanglement engineering would mean that one assigns to a given permutation representing a possible route as the sum of the dimensionless positive integer valued distances $d_{P(i),P(i+1)}$ between subsequent cities in their permutation. The simplest entanglement coefficient defining the reduction probability in the real context is Boltzmann weight $exp(-\sum_i d_{P(i),P(i+1)}/T)$, where T is a real parameter.

   The counterpart of this Boltzmann weight in the p-adic thermodynamics is $p^{\sum_i d_{P(i),P(i+1)}/T_p}$. Here $T_p = 1/n$ is the quantized p-adic temperature using $log(p)$ as a unit. Travelling salesman program is hard since the minima form an analog of spin glass energy landscape. The annealing by varying the value of $T_p = 1/n$ regenerating the entanglement could lead to the deepest valley.

3. The exponent of Boltzman weight could be also seen as a number theoretical analog of a Casimir operator, whose measurement would select the relative Galois representation in the second tensor factor. This kind of operator should have an integer valued spectrum and could define p-adic thermodynamics. The maximal Abelian subgroup of the Galois group could define the observable analogous to free energy.

   The time evolution of spin glass is such that the magnetic relaxation obeys power law rather than exponential law. This suggests that the time evolution for spin glass could correspond to scaling rather than time translation. Therefore the interpretation of the analog of free energy could be in terms of scaling interaction Hamiltonian.

4. This approach could apply to all problems, which can be transformed to the travelling salesman problem. Note that the very large number of problems with varying distances between cities allows the same path as a solution. This would make it possible to transform the problem to a problem in which the distances are integer valued.

7.3.6 Some delicacies related to the Galois group

The considerations above represent only a general vision and reflect my rather amateurish understanding of number theory.

The isotropy group of the Galois group leaving root fixed

One important point, which is not mentioned above, is that since the action of the Galois group permutes the roots of the polynomial P identified as mass squared values, it does not commute with Lorentz and Poincare transformations. This is one excellent motivation for Galois singlet property of the physical states. The entire Galois group would act along time-like braids and in ZEO, where space-time surfaces are fundamental objects and a small failure of the classical determinism takes place, this would make sense.

For a given root, one can identify its isotropy group as the subgroup of the Galois group leaving the root invariant. The isotropy subgroup respects the value of mass squared and therefore can appear as a physical symmetry group.

For a polynomial of degree n with maximal Galois group S_n, this group is S_{n-1}. For $n = 5$ with A_5 with order 60 as Galois group acting at icosahedron, this group is A_4 with 12 elements acting at tetrahedron. Intriguingly, both groups appear in the model of bioharmony and genetic code [L60].

Relationship with Higgs mechanism

Polynomials P have two kinds of solutions depending on whether their roots determine either mass or energy shells. For the energy option a space-time region corresponds by $M^8 - H$ duality to a solution spectrum in which the roots correspond to energies rather than mass squared values and light-cone proper time is replaced with linear Minkoski time [L57, L58]. The physical interpretation of the energy shell option has remained unclear.

The energy shell option gives rise to a p-adic variant of the ordinary thermodynamics and requires integer quantization of energy. This option is natural for massless states since scalings leave the mass shell invariant in this case. Scaling invariance and conformal invariance are not violated.

One can wonder what the role of these massless virtual quark states in TQC could be. A good guess is that the two options correspond to phases with broken *resp.* unbroken conformal symmetry. In gauge theories to phases with broken and unbroken gauge symmetries. The breaking of gauge symmetry indeed induces breaking of conformal symmetry and its breaking is more fundamental.

1. Particle massivation corresponds in gauge theories to symmetry breaking caused by the generation of the Higgs vacuum expectation value. Gauge symmetry breaking induces a breaking of conformal symmetry and particle massivation. In the TGD framework, the generation of entanglement between members of state pairs such that members having opposite values of mass squared determined as roots of polynomial P in the most general case, leads to a breaking of conformal symmetry for each tensor factor and the description in terms of p-adic thermodynamics gives thermal mass squared.

2. What about the situation when energy, instead of mass squared, comes as a root of P. Also now one can construct physical states from massless virtual quarks with energies coming as algebraic integers. Total energies would be ordinary integers. This gives massless entangled states, if the rational integer parts of 4-momenta are parallel. This brings in mind a standard twistor approach with parallel light-like momenta for on-mass shell states. Now however the virtual states can have transversal momentum components which are algebraic numbers (possibly complex) but sum up to zero.

Quantum entangled states would be superpositions over state pairs with parallel massless momenta. Massless extremals (topological light rays) are natural classical space-time correlates for them [K8, K68]. This phase would correspond to the phase with unbroken conformal symmetry.

3. One can also assign a symmetry breaking to the thermodynamic massivation. For the energy option, the entire Galois group appears as symmetry of the mass shell whereas for the mass squared option only the isotropy group does so. Therefore there is a symmetry breaking of the full Galois symmetry to the symmetry defined by the isotropy group. In a loose sense, the real valued argument of P serves as a counterpart of Higgs field.

4. One can also assign a symmetry breaking to the thermodynamic massivation. For the energy option, the entire Galois group appears as symmetry of the mass shell whereas for the mass squared option only the isotropy group does so. Therefore there is a symmetry breaking of the full Galois symmetry to the symmetry defined by the isotropy group. In a loose sense, the real valued argument of P serves as a counterpart of the Higgs field.

   If the symmetry breaking in the model of electroweak interaction corresponds to this kind of symmetry breaking, the isotropy group of the group, which presumably involves also a discrete subgroup of quaternionic automorphisms as an analog of the Galois group. Quaternionic group could act as a discrete subgroup of $SU(2) \subset SU(2)_L \times U(1)$. The hierarchy of discrete subgroups associated with the hierarchy of Jones inclusions assigned with measurement resolution suggests itself. It has the isometry groups of Platonic solids as the groups with genuinely 3-D action. $U(1)$ factor could correspond to Z_n as the isotropy group of the Galois group. In the QCD picture about strong interactions there is no gauge symmetry breaking so that a description based on the energy option is natural. Hadronic picture would correspond to mass squared option and symmetry breaking to the isotropy group of the root.

In the maximally symmetric scenario, conformal symmetry breaking would be only apparent, and due to the necessity to restrict to non-tachyonic subsystems using p-adic thermodynamics.

Part II

PHYSICS INSPIRED MODELS FOR GENOME

Chapter 8

Genes and Memes

8.1 Introduction

In TGD based model of consciousness genes and memes are in very similar position. The quantum self-organization process explains genetic code as an outcome of Darwinian selection basically carried out by dissipation, and also memes should be subject to similar selection. Cognitive codes would be for neuroscience what genetic code is for biology. Hence there are good motivations to guess what the precise form and realization of these codes might be if it really exists. In fact, p-adic length scale hierarchy suggests an entire fractal hierarchy of cognitive codes with quantized durations of the codeword and preferred numbers of bits per code word [**?**] . There exists however some preferred cognitive codes. A simple model for abstraction process leads to an entire hierarchy of genetic codes and one of them explains the basic numbers of the genetic code. A fascinating possibility is that the next level in the hierarchy yields memetic code and also this possibility will be studied in the sequel. Genetic and memetic codes represent particular examples associated with Mersenne primes $p = 127 = 2^7 - 1$ and $p = M_{127} = 2^{127} - 1$.

8.1.1 Combinatorial Hierarchy Of Codes

The basic numbers of genetic code are probably not accidental. This led for more than ten years ago to an attempt to construct a model for abstraction process reproducing the basic numbers of the genetic code.

Genetic code from a model for abstraction process

The simplest model for an abstraction process is based to a repeated formation of statements about statements starting from two basic statements representing the most primitive logical thoughts. If one drops at each step of construction the statement corresponding to empty set in the set theoretic realization of Boolean algebra, one obtains a hierarchy allowing to understand the basic numbers of genetic code.

The outcome is the so called Combinatorial Hierarchy [A16] consisting of the Mersenne numbers $2, M(1) = 3, 7, 127, 2^{127} - 1, ..$ constructed using the rule $M(n+1) = M_{M(n)} = 2^{M(n)} - 1$. The explicitly listed ones are known to be primes. Combinatorial Hierarchy emerges from a model of abstraction process as sub-sequent transitions from level to meta level by forming Boolean statements about Boolean statements of level n and dropping one statement away. Combinatorial Hierarchy results also by constructing the sets of all subsets with empty set excluded starting from two element set. The set of statements at level n can be given a structure of Finite Field $G(M(n), 1)$ if $M(n)$ is prime. The multiplicative groups $Z_{M(n)-1}$ form a nested hierarchy and the coset spaces $Z_{k_n} \equiv Z_{M(n)-1}/Z_{M(n-1)-1}$ are cyclic groups ($k_n = (M(n) - 1)/(M(n - 1) - 1)$). Hilbert's conjecture states that each Mersenne number in the Combinatorial Hierarchy is prime.

Combinatorial Hierarchy based model of genetic code explains the number of DNAs and amino-acids, and the representation of words of the genetic code as triplets of 4 different lower level codewords. Genetic code corresponds to $n = 3$ level of the hierarchy with 127 statements representable as 7-bit sequences with the sequence of seven "0":s dropped away. Only the 64 6-bit

code words can be fully realized and correspond to $(M(3)+1)/2 = 64$ DNA triplets. $k_3 = 126/6 = 21$ equals to the number of amino-acids plus stopping codon. There is a natural imbedding of subgroup Z_{21} identifiable as a representation of amino-acids to the group $Z_{126=6\times 21}$.

More abstractly, at level n the counterparts of DNA triplets correspond to the set $X_{N(DNA)} \subset Z_{M(n)-1}$ of $N(DNA) = (M(n)+1)/2$ statements consistent with a fixed atomic statement (64 for $n = 3$). Atomic statement corresponds to a fixed value, assumed to be one, of a fixed bit in a bit sequence representation and a subset consisting of single element in the set theoretic representation. These statements could be regarded as statements consistent with the axiom defined by the selection of the atomic statement. The counterparts of amino-acids and stopping codon correspond to k_n theorems of a formal system defined by n^{th} level of Combinatorial Hierarchy having a unique imbedding as the group $Z_{k_n} \subset Z_{M(n)-1}$. The DNAs coding for a given "amino-acid" correspond to the special cases of the theorem.

Mapping of DNA code words to amino-acids generalizes to the mapping $x \to x^{k_{n-1}}$ in $Z_{M(n)-1}$ mapping DNA type statements to amino-acid type statements. $(M_(n)+1)/2$ DNAs can be imbedded to Z_{126} with several way. Genetic code is fixed ones this imbedding is given. For $n = 3$ one obtains ordinary genetic code defined by the map $x \to x^6$ and imbedding of the DNAs to Z_{126}. The numbers of DNA:s coding single amino-acid can be reproduced by a symmetry breaking mechanism involving the finite groups $Z_{p_{n-1}}$ and Z_{k_n} and symmetry breaking is in a well defined sense minimal. The infinite hierarchy of possible genetic codes (at least if Hilbert's conjecture holds true) suggests the possibility of an infinite hierarchy of increasingly complex life forms.

If one allows only Mersenne primes, the model for the abstraction process predicts at least one further code, which I have used to call memetic code. It corresponds to the Mersenne prime $M_{127} = 2^{127} - 1$ and has 2^{126} code words and $(2^{126} - 1)/(2^6 - 1)$ "amino-acids". The secondary p-adic time scale $T(2, M_{127})$ is .1 seconds and defines a fundamental time scale in bio-systems.

There are reasons to expect that memetic code is an especially interesting higher level cognitive code and realized in terms of field patterns. In particular intronic portion of DNA could realize memetic codewords as sequences of 21 DNA triplets and memes would define the counterparts of computer programs at DNA level whereas genes would define the counterpart of computer hardware coded into lower level programs and built only when needed. Both memes and genes could express themselves in terms of field patterns.

Memes and genes should relate like computer software and hardware. In the case of language the rules producing a given linguistic expression can be seen as the software whereas words can be seen as the hardware built from phonemes. This leads to the idea that memetic codewords define the basic program modules producing linguistic expressions by activating genes which express themselves as words or word sequences. Phonemes could directly correspond to DNA triplets and define the basic building blocks of language having as such no meaning. If this view is correct, the development of spoken and written language would mean basically the emergence of a higher level of intentionality, which utilizes an already existing repertoire of memes already expressed in many other way. This would in turn suggest that animals and even plants possess some kind of languages realized at cellular level, and that even inter-species communications using common memetic vocabulary.

Myth about Fall of Man as metaphor for codes

There are basically two genetic and memetic codes: 6-bit and almost-7-bit ($2^3 - 1$ code words represented consciously) genetic codes and 126- and almost-127 bit memetic codes. The myth about the Fall of Man provides a little bit tongue-in-cheek metaphor for the extension of 126-bit code to almost-127-bit code. God gave to Adam and Eve the moral code as a single moral law formulated as an atomic statement "Do anything but do not eat from the Tree of Good and Bad Knowledge". Adam and Eve of course did this and probably as many fractally scaled versions.

The first Fall occurred probably already at the molecular level and meant the replacement of 6-bit genetic code with almost-7-bit code: $63 = 9 \times 7$ sins beside 64 good deeds appeared (there are 9 classes of sins containing one sin for every day of the week, one of them containing the seven deadly ones!). Imagination and intentions realized as deeds emerged and Adam and Eve became moral agents. For the memetic code the replacement of 126-bit memetic code led to almost 127-bit code and the repertoire of good and bad deeds was now much more impressive: 2^{126} good deeds and $2^{126} - 1$ sins (the basic classification sins to 7 basic types makes senses still!). One can of

course wonder what was this un-doable sin with strong Gödelian flavor. A code word with only zeros cannot give rise to a conscious experience. Hence the un-doable sin could be such that the sinner cannot experience its consequences in this life, that is suicide.

Genetic code and thinking at DNA level

TGD predicts entire infinite hierarchy of selves starting from elementary particle level so that consciousness should be present also at DNA and protein level. The notion of self indeed allows to understand protein folding, which is rather mysterious phenomenon in standard physics framework.

The physical model of the genetic code constructed in [K56]. when interpreted in terms of the model for an abstraction process, suggests the interpretation of the genetic code as mapping the fundamental 64 truths to 20 basic conscious experiences, perhaps the protein level emotional experience about truth-ness: it must be emphasized that our experiences are probably not in question. Amino-acid P could correspond to the emotionally experienced truth "$G_1(P)$ or $G_2(P)$.. or $G_n(P)$ is true", where G_i code for protein P. 3 stopping sign codewords cannot be experienced emotionally as truths not non-truths (holy trinity at protein level!).

In the model for introns discussed in the chapter [K56] fermionic realization of Boolean statements plays an essential role in the genetic program of eukaryotes and suggests that Boolean mind appears already at molecular level and could correspond to the logical statements represented by genes. This Boolean mind does not correspond to our conscious logical thinking.

Does memetic code emerge at the next level of abstraction process?

The natural question is whether a counterpart of the genetic code could make sense for memes. Combinatorial Hierarchy model for abstraction process that memetic code should correspond to the level M_{127} of the hierarchy. This leads to a precise realization of the memetic code in terms of binary sequences. The secondary p-adic time scale associated with M_{127} is .1 seconds, which seems to define the duration for the immediate subjective memory. If this time scale corresponds to a sequence consisting 127 bits, the duration of single bit is 1/1270 seconds, which happens to be very near to definite p-adic time scale but is somewhat shorter than the typical duration of nerve pulse. This suggests that nerve pulse patterns as such cannot realize the full memetic code. The time scale associated with $k = 252 = 2 \times 6 \times 21$ is.05 seconds and one half of the duration of 127-bit memetic codon. $k = 252$ allows the representations of both 6- and 7-bit genetic codes and of the 126-bit memetic code.

An attractive hypothesis is that the temporal sequences for the Z^0 magnetization directions for a block cognitive antineutrinos at cell membrane space-time sheet provide a representation of the almost 127-bit memetic codeword. The conscious experience results when the Z^0 magnetization directions flip back to the direction of external Z^0 magnetic field in spin flipping cyclotron transition. $M_{127} = 2^{127} - 1$ different conscious experiences results since nothing happens if all cognitive antineutrinos are in the same direction as external Z^0 magnetic field. Z^0 magnetization direction could be altered by the Z^0 magnetic pulse associated with the Z^0 ME inducing cell membrane oscillations of nerve pulse pattern.

This raises obvious questions. Does genome have a memetic counterpart; what would be the function of the memone; what would be the memetic counterparts of the transcription and translation processes for genes? The natural guess is that memes are the basic building blocks of cognition and language. Perhaps also memes are coded by DNA, most naturally by introns, whose portion from the genome increases with the evolutionary level of organism and is 99 per cent for Homo Sapiens. The sequences of 21 DNA triplets would naturally realize 126-bit memetic codons 2^{126} memetic codons at DNA level. The prediction is that the intronic portions of the genome should consist of basic units containing 21 DNA triplets. This would also mean that the language conscious-to-us is only a tip of an iceberg. The intronic part of the DNA would be expressed in terms of MEs and involve communications between cell membrane and nucleus. The dynamics of this realization would be fast and nucleus would play the role of cellular brain.

8.1.2 The Product Model For The Evolution Of Genetic Code

It became as a surprise to me personally that the genetic code has an exact A-G permutation symmetry and an almost exact T-C permutation symmetry with respect to the third nucleotide.

Seen with the eyes of a theoretical physicist knowing the enormous importance of spontaneous symmetry breaking in physics, these simple symmetries point the way to the understanding of the basic mechanism behind the evolution of the genetic code.

This inspired a simple model for our genetic code allowing to see the genetic code as a product of much simpler doublet and singlet codes with a small symmetry breaking due to the interaction between singlets and doublets. This model, even admittedly rather formal, might have deep implications for the theories how the life at the molecular level has involved. The physical realization of this model will be also discussed briefly. A detailed discussion can be found in [**?**].

8.1.3 General Ideas About Codes And Languages

By quantum-classical correspondence space-time sheets provide a symbolic representation for the contents of consciousness. Therefore one can say that everything in principle represents and the task is to understand how these symbolic representations are generated, how codes are established, and how these symbolic representations generated the desired mental images. This obviously means a profound departure from the basic belief system of standard biology.

Computer languages form a hierarchy such that highest level languages are very flexible approaching gradually to the spoken language whereas lowest level languages are very precise and rigid. The notion of self hierarchy suggests that our spoken language is only a top of an iceberg and that below it is a hierarchy of languages ending down to the cellular level and DNA is one particular example about "computer language" realized in terms of p-adic cognitive codes, in particular genetic and memetic codes. In an attempt to understand whether and how memetic and other p-adic cognitive codes might relate to the spoken and written language one must have some general ideas codes and language.

The hierarchy of cognitive codes

p-Adic length scale hypothesis suggests an entire hierarchy of cognitive codes and languages. The primes $p \simeq 2^k$, k integer seems to be interesting physically, and prime values of k seem to be especially interesting. The codes would be characterized by the duration of the codeword given by n-ary p-adic time scale $T_p(n) = p^{(n-1)/2}T_p$, $T_p = 2^{k/2-127}T(2,127)$, $T(2,127) = .1$ seconds. The most general assumption is that number k_1 of bits of the codeword for given integer k_1 corresponds to some factor of k, the largest factor maximizing the information content. Codes could be represented either as temporal sequences of bits represented as pulses of maximal duration $T_p(n)/k_1$ or as superpositions of k_1 harmonics of $f_1 = 1/T_p(n)$, where Fourier components having intensity above/below critical value would represent bit 1/0. These representations will be referred to as pulse and frequency representations. Frequency representations would be realized in terms of topological light rays ("massless extremals", MEs) representing topologically quantized transverse radiation and pulse representations in terms of scalar wave pulses not possible in Maxwell's electrodynamics [K37]. This representational dichotomy reflects particle-wave duality and talking left brain and singing right brain dichotomy.

Memetic and genetic codes represent special examples of cognitive codes. One must distinguish between two representations: the representations involving 6 bits or almost 7 bits and 126 bits or almost 127 bits. "Almost" means that only $2^k - 1$ bit sequences rather than all 2^k bit sequences are realized as conscious bits if bits are realized as phase transitions.

Codes are always involved with classical communications involving transformation of mental images to a symbolic representation by some code. At our level of the hierarchy this symbolic representation could be speech, written language, picture, body language... This would suggest that also p-adic cognitive codes are involved with conscious communications. If these codes are realized in living systems, the bit sequences with the predicted durations and bit contents should induce biological effects serving as correlates for the conscious understanding of the message generated by the codewords at some level of the hierarchy.

TGD based view about living matter relies on the notion of field body or magnetic body associated with any system and having size much larger than the material body. Also these bodies form a fractal hierarchy. The communications from material body to field body could be based on cognitive codes. Given p-adic frequency corresponds f_p to a p-adic length scale $L_p = c/f_p$ characterizing the size of the magnetic body involved and for EEG frequencies the size scale of

Earth is natural unit. For instance, p-adic cognitive codes realized in terms of field patterns would be involved with the communication of long term declarative memories from the geometric past.

What language is?

The attempt to understand the possible role of memetic code, a rough vision about what language is, allows to eliminate several ideas which look promising at first.

1. Language involves generation of symbolic representation of a mental image by a more or less rigid code. An example of a very flexible code is code based on associations. The symbolic representation of mental image should induce in the receiver the original mental image as faithfully as possible. This requires that a lot of common context. In particular, the neurologies and biologies of the sender and receiver must resemble each other sufficiently. In the case of high level languages like ordinary language even this is not enough and only simplest verbal signals and body language are understood universally. The cognitive codes associated with say cell level communications might make possible communications between cells of even different species remaining however unconscious to us.

2. The p-adic vision about evolution of cognitive skills like spoken language is that they evolve from long time and length scales to shorter ones. First a rough sketch about the motor action is created and gradually more and more details are added. This applies also at the level of the evolution of language itself. Simple signals expressing and generating emotions evolve gradually to spoken language which evolves to written language which in turn evolves to computer languages.

3. Learning of language requires learning of the conventions assigning to a given symbol a mental image. Sharing of mental images which represent more primitive "telepathic" communication makes possible this process. The observation that even plants and cells can react to our emotions and that this reaction does not depend much on distance [J10]. suggest that the sharing of mental images is in question. This allows to consider the possibility of inter-species linguistic communications using field patterns.

4. The understanding of language requires transformation of symbolic representation to conscious experience and here the notion of conscious bit ("cbit" [K66]) realized as a phase transition or as an absence of phase transition suggests itself. Phase transition could correspond to magnetization or formation of electret state and living matter could generate these representations in various length scales.

5. In TGD Universe intentions are realized as actions by a process, which proceeds from the magnetic body downwards along the hierarchy much like a desire of a boss of some institution to the lower levels of hierarchy. At each level intention or intentions are transformed to desires communicated to the lower levels of hierarchy. Intentions have p-adic space-time sheets as space-time correlates and are transformed to real ones representing the desire.

The most plausible realization of this process is in terms of time mirror mechanism. The space-time sheets in question would correspond to negative energy topological light rays representing the propagation of signals to the geometric past and induce processes. The process would continue down to the level of neurons and even DNA level and generate the desired action as a reaction to the resulting complex of desires. The beauty of the mechanism is that the communication to the geometric past makes it instantaneous.

Spoken and written language would rely on the same process and could propagate down to the level of genome and select the memes to be expressed. The expression of these memes as field patterns would then be a process propagating upwards in the hierarchy and finally generating speech or written word. When I decide to say something say the words "time mirror", this intention is transformed to a desire communicated to the geometric past to the lower level of the self hierarchy, and that at this level this desire generates further desires communicated to the lower levels. Ultimately this process ends down to the level of cells and even cell nuclei and DNA and induces response which propagates to the higher levels as neural and other activities inducing muscular activities in speech organs and generates the words "time mirror".

The signal to the geometric past involves negative energy photons and topological light rays. The working hypothesis has been that the signal to the geometric past is only a space-time correlate for sharing of the desire to generate the action, and does not involve any code. If this is the case then only the response propagating to the geometric future would be classical signal based on some code. One must however keep mind open to the possibility that also communications to the geometric past involve code.

Conscious bits and cognitive representations

The symbols representing message must be transformed to standardized mental images. The simplest possibility is that the mental images are coded to patterns of conscious bits or cbits. The general model for sensory and other qualia suggests that conscious bits should be realized as quantum jumps sequences associated with phase transitions. In this ways same quantum number increment is occurs for many particle for single quantum jump and for sufficiently long sequence of quantum jumps. Bit 1 would correspond to the occurrence of phase transition and bit 0 to the non-occurrence of the phase transition. For a code of k bits this has important implication: the codeword containing only zeros does not generate any conscious experience so that the number of experienced code words is $2^k - 1$. This could explain why Mersenne primes seem to be define especially important p-adic time scales.

Living matter is populated by dynamical electrets so that phase transitions between ordinary and electret states at various length scales are expected to be of special importance. Also magnetization of super phases at magnetic flux tubes of say Earth's magnetic field is expected to be one mechanism producing basic qualia serving as as bits.

Computer metaphor at DNA level

Software and hardware are essential elements of the computer and at DNA level this could mean that genes code for hardware which is not stable as in case of ordinary computers. This means that computer hardware is replaced by the possibility to generate it and genes carry the information needed for this. Introns would in turn represent the software, the programs and therefore also the linguistic aspect of DNA. An interesting possibility is that introns realize memes as sequences of 21 DNA triplets. This picture allows and even suggests that even DNA level might be involved with the generation of spoken words and define the deep structure of language.

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` [L19].

8.2 Combinatorial Hierarchy And Genetic Code

It is already found that Combinatorial Hierarchy emerges as a unique hierarchy of mappings of Boolean thoughts to association sequences, which could perhaps correspond to nerve pulse patterns, or more probably, to temporal field patterns. In the following the connection of Combinatorial Hierarchy with genetic code is demonstrated.

8.2.1 Combinatorial Hierarchy As A Model For Abstraction Process

One could view the development of intelligence as a process, which takes place as sub-sequent transitions from hierarchy level to a higher hierarchy level, meta-level. First there are statements about concrete things, say numbers. Then come the statements about statements (say theorems about theorems of number theory): "If theorem A is true then theorem B is true". Then come the statements about statements about...

What is remarkable is that the so called Combinatorial Hierarchy [A16] (which emerged first in particle physics context) results from this kind of gradual abstraction process consider Z_2 valued functions. The value 1 might correspond to "true" and 0 to "not true".
i) Assume that lowest level corresponds to 2 statements.
ii) Go to the meta level and consider statements about statements (theorems about theorems in mathematics). Therefore one must consider Z_2 valued Boolean functions in Z_2 corresponding to

statements of type "P is true" and "P is not true": there are altogether 4 of them. Drop the statement represented by $(0,0)$.
iii) Again one goes to meta level and considers statements about statements about statements that is functions from 3-element set to Z_2: 7 elements altogether, when one throws away the statement represented by sequence of zero bits.
iv) Continuing this process one clearly gets Combinatorial Hierarchy.

The somewhat mysterious feature is the dropping of one statement. If the construction corresponds to the construction assigning creation of the cognitive fermion pair with the splitting of a wormhole contact connecting two space-time sheets, then the requirement that the two space-time sheets form a connected structure drops exactly one configuration (no wormhole contacts connecting the two space-time sheets) from consideration. Second interpretation would be in terms of conscious bit. If conscious bit "1" is represented as a phase transition of some kind then the sequence of "0" s is not representable as a conscious bits so that only 2^k-1 code words are representable for k bit code and the only $k-1$ bits are fully representable which suggests that only 2^{k-1} bits represent information and remaining bits could play the same role as parity bits.

There is second construction which is purely set theoretical and gives a natural explanation for the dropping of one statement. Consider subsets of the set $(0,1)$. There are 3 of them if the physically non-realizable empty set is excluded. Consider next the subsets of the 3-element set: there are $2^3-1=7$ of these sets if empty set is excluded. By continuing the process one finds that the numbers of the Combinatorial Hierarchy result. This suggests that the physical non-realizability of $(0,0,...)$ Boolean statement is basic reason for dropping it from consideration.

The numbers of the Combinatorial Hierarchy have some properties, which suggest that they are very closely related to Genetic Code.

1. The numbers $p=3=M_2, 7=M_3, 127=M_7, M_{127}$ are Mersenne primes. It is possible that all the Mersenne numbers $M(n+1)=M_{M(n)}$ of the sequence are primes. This implies that the statements can be given the algebraic structure of Finite Field $G(p,1)$. Therefore the set of the Boolean statements has also interpretation as a simplified model for arithmetics and the arithmetic abilities of the intelligent system grow gradually in transitions from level to meta level. As a consequence the basic conjecture

$$M(n+1) \quad = \quad M_{M(n)} = 2^{M(n)}-1 \text{ prime } n=1,2,... \ , \tag{8.2.1}$$

roughly means that there is no upper bound for the arithmetic abilities of intelligent system!

2. The statements at the level p are of two types: "P is true" and "P is not true" and there are clearly $N(p)=(p+1)/2$ mutually consistent statements at level p. These numbers come as $2,4,64,2^{126},..$ for $p=3,7,127,...$ What is remarkable is that $N(7)=4$ is the number of different DNA:s and $N(127)$ is the number of different DNA sequences. This suggests that DNA: s represent physically consistent with a given atomic statement at level p.

3. The finite field $G(p,1)$ has the cyclic group Z_{p-1} as the multiplicative group of nonzero elements. The dimensions of these groups read as $1,2,6=2\cdot 3, 126=6\cdot 21,...$ for Combinatorial Hierarchy. The multiplicative group of the previous level can be regarded as a subgroup of the next level multiplicative group for the lowest members of the Combinatorial Hierarchy at least: $Z_{p_n-1} \subset Z_{p_{n+1}-1}$. The reason is that $p_{n+1}-1$ is divisible by p_n-1 for the lowest Mersenne primes. In fact divisibility holds true also for $M_{127}-1$ and M_7-1. Divisibility condition gives

$$2^{126}-1 \quad = \quad 63n \ . \tag{8.2.2}$$

The condition is satisfied!: $63=3^2\cdot 7$ divides $2^{126}-1$, whose prime factorization [A17] is given by

n	1	2	3	4
$M(n)$	3	7	127	$2^{127}-1$
$N(DNA,n)=(M(n)+1)/2$	2	4	64	2^{126}
$N(amino,n)=(M(n)-1)/(M(n-1)-1)$	2	3	21	$(2^{126}-1)/63$

Table 8.1: The lowest Mersenne numbers of Combinatorial Hierarchy (known to be primes), the numbers of "DNA" k_{n-1}-plets and the numbers of "amino-acids" for these levels.

$$\begin{aligned} 2^{126}-1 &= 3^3\cdot 7^2\cdot 19\cdot 43\cdot 73\cdot 127\cdot X \ , \\ X &= 337\cdot 5419\cdot 92737\cdot 649657\cdot 77158673929 \ . \end{aligned} \tag{8.2.3}$$

Actually the divisibility follows quite generally from the following little theorem:
Theorem: $M(n)-1$ divides $M(n+1)-1$ always and $M(n)$ divides $M(n+1)-1$ if $M(n)$ is prime. The divisibility of $M(M(n))-1$ by prime $M(n)$ follows as a particular case $a=2, p=M(n)$ of Fermat's theorem stating that $a^{p-1}=1\ mod\ p$ holds true for any natural number a and any prime p. The divisibility of $M(M(n))-1$ by $M(n)-1$ is equivalent with the divisibility of $2^{M(n)-1}-1$ with $2^{M(n-1)-1}-1$. This property holds true for the lowest Mersenne numbers of the Combinatorial Hierarchy and can be proven to hold true generally by induction using the following lemma [A4]:
Lemma: The greatest common multiplier (x,y) for integers $x=2^a-1$ and $y=2^b-1$ satisfies $(2^a-1,2^b-1)=2^{(a,b)}-1$. The proof of the lemma is based on the observation that the polynomial x^n-1 ($x=2$ now) factorizes into a product of factors (x_i^n-1), where n_i is factor of n. For the polynomials x^a-1 and x^b-1 the largest common multiplier is therefore $x^{(a,b)}-1$.
For $a=M(n)-1$ and $b=M(M(n+1))-1$ lemma together with the induction assumption gives $(a,b)=2^{(M(n)-1,M(n-1)-1)}-1=2^{M(n-1)-1}-1$: the result means that $2^{M(n-1)-1}-1=M(n)-1$ divides $2^{M(n)-1}-1=M(n+1)-1$. The prime number property of Mersenne numbers is not needed in the proof.

As a consequence one has an infinite hierarchy of coset spaces $Z_{p_{n+1}-1}/Z_{p_n-1}=Z_{k_n}$, which are also cyclic groups. The first members of this hierarchy are $Z_{k_1)}=Z_2, Z_3, Z_{21}, ...$ Also the groups Z_{k_n} satisfy the condition $Z_{k_n}\subset Z_{k_{n+1}}$ for the lowest values of k with k_1 excluded and an interesting possibility is that k_n divides k_{n+1} quite generally for some number theoretic reason. What is remarkable is that $k_2=3$ is the number of DNA: s in DNA triplets and $k_3=21$ is the number of amino-acids plus stopping sign coded by DNA: s. This observation suggests that amino-acids correspond to the subset of the statements of $G(p_n,1)$ imbeddable as subgroup Z_{k_n} to Z_{p_n-1} for $p_n=127$. A little consideration shows that the map $x\to x^{k_{n-1}}$ gives a unique embedding for the amino-acid type statements to Z_{p_n-1}.

These observations suggest a general model for Genetic Code. The 64 DNA sequences give a physical representation for the statements compatible with a given atomic statement at $p=127$ level of the Combinatorial Hierarchy. The choice of these mutually compatible statements as a subset of $G(127,1)$ is by no means unique and is determined by the evolution. The 21 amino-acids (stopping sign is regarded formally as "amino-acid") at $p=127$ level correspond to the unique statements representable in the form $y=x^6$ in Z_{126} and form cyclic group Z_{21}. Genetic code can be regarded as the mapping $x\to x^6$ mapping all DNA type statements to amino acid type statements. The interpretation of the amino-acid type statements is as general axioms and DNA type statements are regarded as special cases of these axioms. Amino-acid sequences in turn are regarded as theorems derivable from axioms by constructing amino-acid sequences: the direction of the sequence is unique by the chirality of the amino-acid molecules.

The formation of theorems in formal system indeed corresponds to the formation of symbol sequences by some rules (now the rules are extremely simple, perhaps too simple!). The representability of DNA: s as triplets of 4 basic units has explanation: actually a more general the formula $N(DNA,n)=(p_n+1)/2=((p_{n-1}+1)/2)^{k_{n-1}}=N(DNA,n-1)^{N(amino,n-1)}$ holds true for all levels of the Combinatorial Hierarchy. In particular, for $p=127$ one has $64=4^3$. Actually an infinite hierarchy of Genetic Codes suggests itself: for the n: th member of the Hierarchy there

d	6	4	3	2	1
N	3	5	2	9	2

Table 8.2: The number of amino acids N associated with a given degeneracy d telling the number of DNA triplets mapped to the amino acid in genetic code. The degeneracies are always smaller than 7 as predicted by the proposed explanation of the Genetic Code.

are k_n axioms and if k_n divides k_{n+1} the axioms of level n are imbeddable as a subgroup Z_{k_n} to the group $Z_{k_{n+1}}$ of axioms at level $n+1$ and the counterpart of Gödel's Incompleteness Theorem holds true.

8.2.2 Interpretation Of Genetic Code

Finite Field Computer picture leads to the interpretation of genetic code as a map from the set of well defined truth values $X_{64} \subset G(127,1)$ (DNA: s) to the set $Z_{126}/Z_6 = Z_{21} \subset G(127,1)$ (amino-acids).

1. The interpretation of the previous observation is that amino-acids and "stopping sign" correspond to the elements x of the coset space $Y = Z_{126}/Z_6 = Z_{21}$ obtained by identifying two elements a and b of Z_{126} are identified if $a^6 = b^6$ holds true. The realization of Z_{21} as a subset of $G_{127,1}$ is obtained as the set of non-vanishing sixth powers of $G(127,1)$ elements

$$z \in Z_{21} <=> z = x^6, \quad 0 \neq x \in G(127,1) \ . \tag{8.2.4}$$

   Since a coset space is in question $d = 126/21 = 6$ elements of Z_{126} are mapped to a given element of Z_{21} in the map $x \to x^6$.

2. According to the proposed model of intelligent system DNA triplets correspond to a subset X_{64} of 64 well determined truth values of $p = 127$ logic but at this stage there is no first principle telling which subset corresponds to truth values. Let us however assume that X_{64} corresponds to subset of Z_{126} so that zero element is excluded from X_{64}.

3. With these identifications genetic code correspond to the mapping $x \to x^6$ from the set X_{64} of well defined truth values to Z_{21}

$$x \in X_{64} \quad \to \quad x^6 \in Z_{21} \ . \tag{8.2.5}$$

   The number of DNA triplets d coding same amino acid is just the number of elements of X_{64} mapped to same element of Y and this gives strong constraints for the identification of X_{64} as subset of $G(127,1)$. Clearly, genetic code is to a high degree equivalent with the identification of 64-element DNA triplets as subset of Z_{126}. The identification of X_{64} as subset of Z_{126} cannot however be determined uniquely since the group Z_6 acts as the symmetry group of the code permuting the 6 elements of Z_{21} mapped to same element of Z_{126} and leading to a code with same degeneracies d.

An important prediction is that at most six DNA triplets can correspond to same amino acid. As**Table 8.2** shows, the condition is satisfied: there are three amino acids for which DNA degeneracy d is 6. This means that it is indeed possible to realize genetic code in the proposed manner.

One can consider first simple guesses for the identification of X_{64} as a subset of $G(127,1)$. The identification as even elements $y = 2k$, $k = 0,63$ is not possible since zero cannot belong to X_{64}: same applies to the identification as odd elements. The identification as the elements

expressible as squares $y = x^2$ is excluded for the same reason. One could include the 64^{th} DNA by identifying it as an arbitrary element of Z_{126}. All these identifications yield almost completely symmetric genetic code: $d = 3$ for all 21 amino acids except one for with one has $d = 4$ so that something more complicated is needed.

8.2.3 Genetic Code As A Result Of Geometric Symmetry Breaking

One could try to understand the pattern of degeneracies as a symmetry breaking pattern, but not in terms of group representations as is done usually but in terms of group orbits. For single DNA multiplet associated with given amino-acid the natural symmetry group is Z_6 or some of its subgroups and DNA multiplet of given amino-acid can be regarded as a union of orbits for the subgroup in question. The subgroups of $Z_{126}/Z_6 = Z_3Z_7$ in turn can transform the DNA multiplets with same degeneracy to each other and amino-acids with same degeneracy can be regarded as a union of orbits of Z_7, Z_3 or Z_1. This symmetry pattern seems to work!

1. Consider first the group Z_6 acting inside DNA multiplets associated with given amino-acid. The definition of Z_{21} implies that the DNA: as associated with $d = 6$ amino-acids must be identified as six-element orbits of Z_6 symmetry. $d = 3$, $d = 2$, $d = 1$ amino acids correspond to the breaking of Z_6 to Z_3, Z_2 and to Z_1 respectively. $d = 4$ amino-acids are however problematic since Z_6 does not have 4-element subgroup. One can interpret $d = 4$ DNA: s either as a union of two Z_2 orbits or as a union of Z_3 and Z_1 orbits: Z_1 orbit corresponds most naturally to the mirror image of one Z_3 point, when the points of Z_{126} are represented as points of unit circle. This interpretation seems to be more appropriate.

2. Consider next the group Z_{21} acting on amino-acids. The 3 $d = 6$ amino-acids could be identified as an orbit of $Z_3 \subset Z_{21}$. If one regards the 5 $d = 4$ multiplets as unions of Z_3 and Z_1 orbits one can obtain altogether $2+5$ $Z_3 \subset Z_6$ orbits, which could be regarded as Z_7 orbit. What remains is $5+2 = 7$ Z_1 orbits, which could be regarded as Z_7 orbit. Therefore it seems that amino-acids can be ordered nicely into the orbits of Z_3 and Z_7. It turns however that exact symmetry is broken and some orbits are slightly deformed or even broken to pieces.

There are good reasons for symmetry breaking.

1. Besides symmetry also redundancy of the genetic code is desirable: this means that the number of the amino-acids with small degeneracy should be as small as possible. Z_6 (or some subgroup) symmetry and redundancy are competing factors since average degeneracy is always same and symmetry tends to increase the redundancy associated with some amino acids. Therefore redundancy requirement might be one underlying reason for symmetry breaking.

2. It turns out that also the competition between symmetries Z_3 and Z_7 in Z_{27} forces either Z_7 or Z_3 symmetry breaking already before the "actual" symmetry breaking.

3. The third reason for the symmetry breaking is the constraint that the numbers of DNA triplets and amino-acids are constrained to 64 and 21 respectively. For, instance 63 DNA: s allows representation as a union 9 Z_6 orbits having $Z_3 \subset Z_{21}$ as symmetry group but for 64 DNA: s there is necessarily one Z_1 orbit present.

It would be nice if one could understand the genetic code as a small perturbation of some code with both high symmetry and high redundancy. One could even assume that the number of amino-acids before the symmetry breaking is smaller than 21 so that symmetry breaking is necessary to obtain 21 amino-acids. A geometric picture of the situation is obtained by regarding the points of Z_{126} as points $\Phi = n2\pi/126$ of a unit circle endowed with standard metric so that it becomes possible to define what "small" symmetry breaking means.

8.2.4 Symmetry Breaking Scenarios

The genetic code can be reproduced as the following symmetry breaking pattern.

1. Unbroken symmetry corresponds to the following situation. There are $6 = 3 + 3$ amino-acids with maximal degeneracy $d = 6$ and 7 amino-acids with degeneracy $d = 4$: altogether $13 < 21$ so that symmetry breaking is necessary. $d = 6$ multiplets correspond to 6 Z_6 orbits $\Phi = n2\pi/6 + k\Delta(i)$, with $\Delta(i) = k_i 2\pi/126 < 2\pi/6$. Single $d = 4$ multiplet corresponds to Z_3 orbit plus single point, which is diametrically opposite to one of the points at Z_3 orbit. More explicitly: basic $(3, 1)$ multiplet corresponds to the Z_3 orbit $\Phi_3(k) = 6\Delta + k2\pi/3$, $k = 0, 1, 2$ plus the point $\Phi_1 = 6\Delta + \pi$. By acting on this orbit with rotations $\Delta_1(i) = k_i 2\pi/126$, $i = 0, ..., 6$, $\Delta_1(i) < 2\pi/6$ one obtains 7 $d = 4$ multiplets. Obviously one must have $\Delta(i) \neq \Delta_1(j)$ for each i, j pair in order to avoid overlapping. The actual embedding of Z_6 multiplets is not relevant for the degeneracies of the genetic code and will be discussed later.

2. The first symmetry breaking is $Z_6 \to Z_2$ and occurs for 3 $d = 6$ amino-acids and leads from 3 Z_6 orbits to 9 Z_2 orbits so that 9 $d = 2$ amino-acids result. Breaking can be understood geometrically as follows. Single $d = 6$ multiplet is obtained by Z_2 action (reflection) from Z_3 orbit, say $\Phi(k) = k2\pi/3$. What happens is that two points on Z_3 orbit that for Z^3 orbit the points $\Phi(k)$ with $k = 1$ and 4 are rotated slightly with different rotation angles

$$\begin{aligned}
\Phi(1) &\to \Phi(1) + \delta_1 \ , \\
\Phi(4) \to \Phi(4) &+ \delta_1 \ , \\
\Phi(5) &\to \Phi(5) - \delta_2 \ , \\
\Phi(6) &\to \Phi(6) - \delta_2 \ , \\
\delta_i &= \frac{k_i 2\pi}{126} \ , \\
1 < k_i &< 6 \ .
\end{aligned} \tag{8.2.6}$$

   Here δ_i must be chosen so that the deformed points do not coincide with already "occupied" points. Minimal symmetry breaking is obtained with $k_1 = 1 = k_2$ but would lead to overlapping. One must also have $k_1 \neq k_2$ ($k_1 = k_2$ would imply additional reflection symmetry). The symmetry breaking leads to $9 + 7 = 16$ amino acids with degeneracies $d \geq 2$.

3. The second symmetry breaking leads from 7 $d = 4$ multiplets to 5 $d = 4$ multiplets, 2 $d = 3$ multiplets and 2 $d = 1$ multiplets. What happens is that 2 basic $d = 4$ multiplets consisting of Z_3 orbit and mirror image of one of Z_3 points is deformed $d = 3$ plus $d = 1$ multiplet: this is achieved if mirror image point is slighly shifted. The deformation is obtained by performing for the basic multiplet ($\Phi_3(k) = k2\pi/3, \Phi_1 = \pi$) the deformation

$$\Phi_1 = \pi \quad \to \quad \pi \pm \delta_3 \ . \tag{8.2.7}$$

   $\delta_3 = k_3 2\pi/126$, $1 < k_3 < 6$ followed by appropriate rotation carrying broken multiplet to its own position. $k_3 = 1$ is not allowed since it would lead to overlapping and $k_3 = 2$ leads to the smallest possible symmetry breaking.

One can try to find unique embedding of X_{64} (and also try to understand the uniqueness of the genetic code) by requiring that amino-acids form orbits of Z_{21} or its subgroups. Z_3 and Z_7 are competing symmetries and not consistent with each other: the reason is that Z_3 orbits and Z_7 orbits in same basic angular range of length $2\pi/6$ necessarily overlap since between two points of Z_3 orbit there are always just 6 points so that Z_7 orbit cannot be put between two points on Z_3 orbit. Therefore one must choose between either enhanced Z_3 or Z_7 symmetry for the embedding of X_{64}.

Consider first Z_3 symmetric situation.

d	N(d)	$\Phi/\Delta = n \ mod \ 126$, $\Delta = 2\pi/126$
6	3	$n = A(i) + B(k)$, $A(i) = 21i$, $B(k) = 7k$, $i \in I$, $k \in K$
		$I = \{0, 1, .., 5\}$, $K = \{0, 1, 2\}$
2	9	$n = (A(i) + B(k) + 1 + \delta_1(i))$, $i \in I$, $k \in K$
		$\delta_1(0) = \delta_1(3) = 0$, $\delta_1(1) = \delta_1(4) = -3$, $\delta_1(2) = \delta_1(5) = 4$
4	5	$n = i + 42k$, $n = i + 63$, $i = 2, 10, 11, 17, 18$, $k \in K$
3	2	$n = i + 42k$, $i = 3, 4$, $k \in K$
1	2	$n = i + 63 + \delta_2(i)$, $i = 3, 4$, $\delta_2(3) = -1$, $\delta_2(4) = 1$

Table 8.3: Explicit form for the Z_3 symmetric embedding of X_{64} consistent with Genetic Code. The index k appearing in the formulas labels points on Z_3 orbit. The embedding is illustrated in **Fig. 8.1**.

d	N(d)	$\Phi/\Delta = n \ mod \ 126$, $\Delta = 2\pi/126$
6	3	$n = A(i) + B(k)$, $A(i) = 21i$, $B(k) = 7k + \delta_1(k)$, $i \in I$, $k \in K$
		$I = \{0, .., 5\}$, $K = \{0, 1, 2\}$, $\delta_1(1) = 5$, $\delta_1(0) = delta_1(2) = 0$
2	9	$n = A(i) + \delta_2(i) + 1 + B(k)$, $i \in I$, $k \in K$
		$\delta_2(1) = \delta_2(4) = -2$, $\delta_2(2) = \delta - 2(5) = 2$,
4	5	$n = 3 + i + 42k$, $n = i + 63$, $i = 2, ..., 6$, $k \in K$
3	2	$n = 3 + i + 42k$, $i = 1, 7$, $k \in K$
1	2	$n = i + 63 + \delta_3(i)$, $i = 1$ *or* 7, $\delta_3(1) = -1$, $\delta_3(7) = 1$

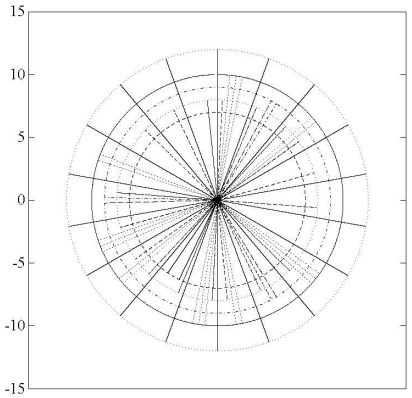
Table 8.4: Explicit form for the Z_7 type embedding of X_{64} consistent with Genetic Code. The embedding is illustrated in figure **??**.

1. $6 = 3+3$ Z_6 orbits decompose naturally into two orbits of Z_3. The first Z_3 orbit corresponds to $\Phi(k, m) = 6m \cdot 2\pi/126 + k2\pi/6$, $m = 0, 1, 2$ and second Z_3 orbit is obtained from this orbit by a rotation $\Delta\Phi = 2\pi/126$. When Z_6 orbits break down to 9 Z_2 orbits the Z_2 orbits can form 3 separate orbits of Z_3.

2. The graphical experimentation with various possibilities shows that one must split Z_7 orbit to three pieces $7 = 1 + 2 + 2 + 2$ so that the 2: s form Z_3 orbit. Therefore complete breaking of Z_7 symmetry makes possible additional Z_3 symmetry. This means that one $d = 4$ orbits arrange into 2 Z_3 orbits and one Z_1 orbit before symmetry breaking. After the symmetry breaking the 2 $d = 3$ multiplets and $d = 3$: s belonging to 5 $d = 4 : s$ form still Z_3 orbits but two $d = 1$: s are thrown out of corresponding Z_3 orbits.

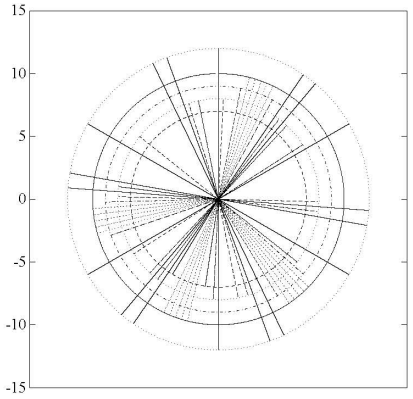
3. An example of an embedding satisfying these constraints is given by the following formulas

Consider next Z_7 type scenario. 7 $d = 4$: s can be put into single Z_7 orbit. $d = 6$ representations cannot however form neither Z_7 full orbits nor full Z_3 orbits in this case. After the symmetry breaking the 2 $d = 3$ multiplets and $d = 3$: s belonging to 5 $d = 4 : s$ form still Z_7 orbits but two $d = 1$: s are thrown out of corresponding Z_7 orbits. There exists no full Z_7 orbit consisting of amino-acids with same d after symmetry breaking so that in this sense Z_7 sceneario possesses much less symmetry than Z_3 scenario. An explicit example is given by the following formulas



1

Figure 8.1: The embedding $X_{64} \subset Z_{126}$ reproducing Genetic Code and possessing Z_3 type symmetry. The lengths of radial lines are $6 + d$, where $d = 1, 2, 3, 4, 6$ is the number of DNA: s associated with amino-acid. The angular distance between points on Z_3 (Z_7) orbits is to 20 (2.85) degrees.



1

Figure 8.2: Z_7 type embedding $X_{64} \subset Z_{126}$ reproducing Genetic Code. Symmetry breaking is much larger for this embedding although visually the embedding looks perhaps more symmetric than Z_3 type embedding.

$N(d=1)$	$N(d=2)$	$N(d=3)$	$N(d=4)$	$N(d=6)$
0	12	0	7	2
2	**9**	**2**	**5**	**3**
4	6	4	3	4
6	3	6	3	5

Table 8.5: The 4 possible genetic codes assuming unbroken initial Z_3 symmetry with numbers of amimo acids with same degeneracy.

8.2.5 In What Sense The Physical Genetic Code Is Unique?

The proposed symmetry breaking scenario is certainly not the only one. A constraint on symmetry breaking patterns comes from the requirement that all amino acids are coded. In terms of orbit multiplicities $g(k)$ (number of amino acids with same number of DNA: s) one has two conditions

$$\begin{aligned} \sum_{k=1,2,3,4,6} g(k) &= 21 \ , \\ \sum_{k=1,2,3,4,6} g(k)k = 64 \ . \end{aligned} \tag{8.2.8}$$

$k=4$ case corresponds to two Z_3 and Z_1 orbits associated with single amino acid. This gives

$$\begin{aligned} g(1) &= -22 + g(3) + 2g(4) + 4g(6) \ , \\ g(2) &= 43 - 2g(3) - 3g(4) - 5g(6) \ . \end{aligned} \tag{8.2.9}$$

This means that all possible genetic codes are labeled by the three integers $g(3), g(4)$ and $g(6)$. The conditions imply

$$\begin{aligned} g(3) + 2g(4) + 4g(6) &\geq 22 \ , \\ 2g(3) + 3g(4) + 5g(6) &\leq 43 \ . \end{aligned} \tag{8.2.10}$$

These conditions restrict the possible symmetry breaking scenarios. In particular, $g(6) \leq 8$ must hold true so that maximal symmetry corresponds to the codes with $(g(3), g(4), g(6))$ equal to $(1, 0, 8)$ or $(0, 1, 8)$.

In the proposed symmetry breaking scenario the number of DNA: s is automatically fixed to 64 and the only requirement is that deformation of X_{64} is such that the number of amino-acids is not smaller than 21. If one assumes that the only symmetry breakings are of form $6 \to 3 \cdot 2$ and $4 \to 3 + 1$ and denotes the numbers of broken $d = 6$ and $d = 4$ multiplets with k_6 and k_4 respectively the condition for 21 amino acids reads as $(6 - k_6) + 3k_6 + (7 - k_4) + 2k_4 = 21$, which gives $k_6 = 4 - k_4/2$, $k_4 = 0, 2, 4, 6$. k_4 gives the number of $d = 1$ amino-acids and $k_4/2 + 2$ gives the number of the unbroken 6 orbits: these numbers clearly measure redundancy and symmetry. The numbers of amino-acids with various degeneracies are given by

$$\begin{aligned} N(d=1) = N(3) &= k_4 \ , \\ N(2) &= 3(4 - k_4/2) \ , \\ N(4) &= 7 - k_4 \ , \\ N(6) &= 2 + k_4 \ . \end{aligned} \tag{8.2.11}$$

Table 8.5 summarizes the 4 genetic codes possible under these assumptions.

The physically realized genetic code (second row) is clearly a compromise between symmetry and redundancy. By the previous construction the physically realized code is characterized by additional symmetry: namely the group $Z_3 \subset Z_{21}$ transforming both 3 $d = 6$ amino-acids and

3 triplets of $d = 2$ amino acids to each other. For all other Z_3 type alternatives this symmetry is broken. Therefore the physical genetic code corresponds in a well defined sense to minimal symmetry breaking.

8.2.6 Hierarchy Of Genetic Codes?

Genetic Code generalizes to an entire hierarchy of genetic codes at formal level, at least.

1. The spaces $X_4 \subset X_{64} \subset X_{(M_{127}+1)/2} = X_{2^{126}} \subset ....$ an be regarded as a hierarchy of "DNA triplets".

2. The preceding results suggest that the multiplicative groups associated with the Combinatorial Hierarchy form also a hierarchy: $Z_2 \subset Z_6 \subset Z_{126} \subset Z_{M_{127}-1} \subset .....$ This is true if the dimensions divide each other: $2|6|126|M_{127}-1|.....$ 126 indeed divides $M_{127}-1 = 2(2^{126}-1)$ and the number of "amino-acids" at the third level is $(2^{126}-1)/63$! The result holds generally from Fermat's theorem ($2^{p-1} = 1 \; mod \; p$) if the Mersenne numbers of the Combinatorial Hierarchy are primes.

3. If Combinatorial Hierarchy consists of primes the coset spaces $Z_6/Z_2 = Z_3 \subset Z_{126}/Z_6 = Z_{21} \subset Z_{M_{127}-1}/Z_{126} \subset ....$ exist and form a hierarchy of "amino-acids".
   The redundancy of the genetic code could be interpreted as resulting from a hierarchy of discrete gauge symmetries: Z_{M_n-1} acts as gauge symmetry in the space $Z_{M_{M_n}-1}$.

There is still further apparent numerical co-incidence. For the first 3 levels the numbers of "amino-acids" are

$$\begin{aligned} a_0 &= 2 \; , \\ a_1 &= 3 \end{aligned} \tag{8.2.12}$$

per,

$$\begin{aligned} a_2 &= 21 \; , \\ a_3 &= ((M_{127}-1)/2)/((M_7+1)/2)) = (2^{126}-1)/63 \; . \end{aligned} \tag{8.2.13}$$

The numbers of "DNA" -n-plets (well defined truth values) are

$$\begin{aligned} d_0 &= 2 \; , \\ d_1 &= 4 = 2^2 = d_0^{a_0} \; , \\ d_2 &= 64 = 4^3 = d_1^{a_1} \; , \\ d_3 &= 2^{126} = 64^{21} = d_2^{a_2} \; . \end{aligned} \tag{8.2.14}$$

The formulas imply that one can construct the physical DNA-triplets at level 2 as $d_2 = d_1^{a_1} = 4^3$ triplets of DNA molecules. At level 3 one can construct $d_3 = d_2^{a_2} = 63^{21} = 2^{126}$ "DNA" 21-plets of 64 different DNA-triplets. More generally, DNA-plets at given level n correspond to a_{n-1}-plets of DNA formed from the DNA-plets of the previous level since the identity

$$d_n = \frac{(M_n+1)}{2} = d_{n-1}^{a_{n-1}} = 2^{a_{n-1}a_{n-2}a_{n-3}...a_0} \; . \tag{8.2.15}$$

holds true in general since the groups Z_{M_n-1} forms a hierarchy of nested subgroups.

The result means that the concrete physical representation of truth values of M_n logic as "DNA" sequences is an internal property of the Combinatorial Hierarchy. The immediate prediction is that sequences of 21 DNA-triplets should code for $a_3 = (2^{126}-1)/63$ generalized amino-acids consisting of sequences of 21 amino-acids acids: these units could be regarded as some kind of "pre-genes". The number of amino-acid sequences consisting of 21 amino-acids (of order 2^{91}

is much smaller than the number of generalized amino-acids (of order 2^{120}), which means that the ordinary amino acids cannot provide an optimal realization of DNA sequences: many generalized amino-acids have no DNA sequence as their representative. DNA sequences are known to contain passive sections, introns, which do not code DNA. An interesting question is whether these sections could represent M_{127} level sequences: if so the number of DNA triplets in these sections should be a multiple of 21.

If the lowest level of the Hierarchy is present DNA: s should be representable as doublets formed from two different $p = 3$ "pre-DNA": s and these should code for 3 different "pre-amino-acids". This kind of structure is not realized in Nature so that the $p = 7$ level of DNA: s is in this sense irreducible.

8.2.7 The Structure Of The Negation Map

The negation map mapping statement to its negation is highly non-unique unless it possesses symmetries and it is interesting to find what one can conclude about the structure of this map by symmetry arguments.

1. For each amino-acid type general statement there are six special cases of the statement. The fact that only 64 statements are actually consistent with a given atomic statement means that some special cases associated with different amino-acids correspond to statement and its negation whereas two points at given Z_6 orbit cannot correspond to a statement and its negation.

2. 62 negations of 64 DNA type statements belong to Z_{126}. One lacking negation corresponds to the zero element of $G(127, 1)$ and the second one corresponds to the excluded statement in the construction of the Combinatorial Hierarchy. One can associate to each amino-acid definite number of negations as the number of elements in the complement of DNA type statements on the Z_6 orbit defined by amino-acid (at Z_6 orbit all statements must be consistent with a fixed atomic statement). These numbers are $d_1 = 0$ for 3 $d = 6$ amino-acids, $d_1 = 2$ for 5 $d = 3 + 1$ amino-acids, $d_1 = 4$ for 9 $d = 2$ amino-acids and $d_1 = 5$ for the 2 $d = 1$ amino-acids so that negations "code" only 18 amino-acids so that duality symmetry between statements and their negations is not possible.

3. Negation must map statements at given orbit to a different orbit. It is however natural to require that points on same orbit, say A, are mapped on same orbit, say B, if possible and that the angles and ordering of points belonging to same orbit are preserved in negation map. More generally, the ordering of points on circle should be preserved.

4. For 2 $d = 3$ amino-acids, call them a and b, the Z^3 orbit a (b) is mapped to the complement of Z^3 orbit b (a). The map is unique apart from Z^3 rotation.

5. For 9 $d = 2$ amino-acids Z^2 orbits (pairs of diametrically opposite points) form 3 Z^3 orbits and Z^3 rotation plus a rotation inside Z^6 orbit gives good candidate for negation map. As a consequence 9 Z_2 orbits in the complement remains "free" and form 3 Z_3 orbits, call them G_i.

6. It is natural map $d = 6$ orbits to these free 9 Z_2 orbits in Z_3 symmetric manner, which means that the content of single Z_6 orbit i is mapped into 3 $d = 2$ orbits in G_i. Diametrically opposite point pair on Z_6 orbit is mapped to a similar point pair in G_i. The map is unique if one requires that Z_6 element on the initial orbit goes to same Z_6 element on the final orbit and this in turn makes the map of 9 Z_2 orbits unique apart from reflection.

7. The 5 $d = 3 + 1$ amino-acids form unions of diametrically opposite point pair A_i plus point pair B_i, $i = 1, ..., 5$ separated by angle of 120 degrees. Point pairs B_i can be mapped to the mirror image $\bar{B}_j$ of B_j, $j \neq i$: one can require that cyclic ordering of pairs B_i is preserved in map to remove part of the non-uniqueness. $2 + 2$ pairs A_i can be mapped to the $2 + 2$ pairs C_i in the complements of 2 $d = 1$ orbits containing 5 points each (2 diametrically opposite pairs C_i plus single point). The remaining pair, say A_{i_0}, can be mapped to zero element of $G(127, 1)$ and to the "dropped out" statement.

8. Denoting the mirror images of 2 $d = 1$ statements a and b by $\bar{a}$ and $\bar{b}$ the negation map for them reads as $(a, b) \to (\bar{b}, \bar{a})$.

8.2.8 Combinatorial Hierarchy As A Hierarchy Of Formal Systems

Usually [A10] formal system is understood as a system of symbols, axioms interpreted as allowed basic strings of symbols and rules for constructing new sequences from the symbols. In [A10] the exciting analogies between the symbol sequences of formal systems and DNA and amino acids sequences and Genetic Code were emphasized and it indeed seems that more than analogy is in question. The model for the Genetic Code suggests an interpretation of Combinatorial Hierarchy as a hierarchy of formal systems with DNA type statements identifiable as a maximal set of 64 statements consistent with an atomic statement (single bit fixed) and amino-acid type statements as basic axiom type truths. Genetic code results from the necessary but non-unique selection of these statements consistent with a fixed atomic statement and the selection of these statements could be a result of fight for survival at the level of amino-acids. The rule for forming statements in this system is simple: just form DNA sequences with building blocks consisting of a_{n-1}(number of "amino-acids" at level $n-1$) DNA-sequences of previous level. Theorems are obtained by coding these statements to amino-acid sequences.

Consider first DNA type statements.

1. It was already suggested that the elements of Finite Fields in the Combinatorial Hierarchy correspond to a hierarchy of statements about statements about.... and therefore a sequence of formal systems formed from basic formal system by successive construction of meta level statements.

2. Finite Field provides a language to construct all possible statements. As already found, the $(p+1)/2$ (p is Mersenne prime in the Combinatorial Hierarchy) statements correspond to maximal set of statements consistent with a fixed atomic statement of this formal system. This is indeed a possible interpretation. Combinatorial Hierarchy was constructed by starting from a set containing just two statements 1 and 0. In the first $p = 3$ level one forms 4 statements about these two statements and drops the one representable as $(0, 0)$. There are however 2 contradictory statements of type P and *not* P in this set so that only $2 = (p+1)/2$ statements are consistent with a given atomic statement in the real world. At the level p one has $p = M_n$ statements about lower level statements and by construction $(p-1)/2$ statements P have also their negation in the set of all possible statements so that $(p+1)/2$ consistent statements with a fixed atomic statement are possible. Thus the conclusion is that 64 DNA triplets represent the maximum number of mutually consistent statements at level $p = M_7 = 127$ of a formal system possibly having a hierarchy of meta levels.

Consider next the interpretation for the set $Z_{k_n} = Z_{p_n-1}/Z_{p_{n-1}-1}$, $k_n = (p_n-1)/(p_{n-1}+1)$ of amino-acid type statements.

1. In any formal system there are two kind of meta statements that is statements $P(Q_1, ..Q_n)$ about statements. The first class corresponds to theorems $P(Q_1, ...Q_n)$ without any reference to the particular value of statements Q_i: a simple example is general theorem stating the conditions under which an orthogonal triangle with two integer sides is Pythagorean triangle: $m^2+n^2 = l^2$ with m, n, l integers. Second class corresponds to the theorems with $(Q_1, ..., Q_n)$ possessing definite values: a simple example is previous theorem for triangle having sides $2, 1$ and 3: $2^2 + 1^2 = 3^2$. The set of "amino-acid" type statements does not depend on the choice of the choice fo the $(p+1)/2$ statements consistent with a given atomic statement and this suggests the interpretation "amino-acid" type statements as general axiom like truths without any reference to the values of the argument of the statement.

   What is special in the proposed hierarchy of formal systems that the substitution operation corresponds to the multiplication of Z_k element with the element $Z_{p_{n-1}-1}$. The introduction of mutual consistency by selecting $(p+1)/2$ special statements implies that the number of DNA: s per amino-acid corresponds to the number of special cases associated with a given "axiom" depends on the "axiom". There is still upper bound for special cases given by $p_{n-1} - 1$.

2. In a good formal system the choice of DNA type statements should be such that there is at least one statement per each truth. The most important truths (as far as survival is considered) should correspond to full $Z_{p_{n-1}-1}$ orbits.

Gödel's Incompleteness Theorem was one of the basic themes in the book of Hofstadter [A10]. Theorem states that in any sufficiently complicated formal system (, that is, practically interesting) there are truths, which are not provable. The Incompleteness Theorem seems to have its analog in bio-systems. As already observed at the level M_{127} DNA sequences consisting of 21 triplets correspond to true statements, which can be regarded as special cases of general truths, whose number is $(2^{126-1})/63 \sim 2^{120}$. Amino-acid sequences consisting of 21 amino-acids give a natural realization for a subset of these truths and the genetic code map is induced from the Genetic Code at the basic level $p = 127$. The number of the truths given by these sequences is of order $20^{21} \sim 2^{91}$ (taking into account the reduction caused by the stopping sign) and much smaller than all possible truths. The interpretation is that the number of possible theorems obtained by forming amino-acid sequences is much smaller than the number of truths. One could always add "axioms" by realizing the remaining truths in some new manner but since the number of levels in the Combinatorial Hierarchy is infinite (assuming that the Mersenne numbers in question are primes) there are always unprovable truths in the system. One can obviously classify the formal systems according to which level is the basic irreducible level inducing genetic code at higher levels.

$p = 7$ ($n = 2$) and $p = 3$ ($n = 1$) level as the defining, irreducible level are also in principle possible.

1. At level $p = 7$ 4 doublets of level $p = 3$ "DNA" code 2 "pre-amino-acids" plus stopping sign and at the next level this coding induces $2^3 = 8 < 21$ different "amino-acids" since stopping sign does not appear in theorems. If stopping sign would correspond to actual amino-acid there would be $3^3 = 27 > 21$ theorems so that the number of theorems would be larger than the number of truths!

2. At level $p = 3$ 2 "DNA": s of code one amino-acid plus stopping sign so that genetic code is one-to-one.
   An interesting possibility is that $p = 3$ and $p = 7$ levels might have been defining, irreducible levels for bio-systems at some early stage of evolution. These formal systems can be regarded as a subsystem of the full DNA-amino-acid system. RNA-triplets of form UXY, $X, Y \in \{A, C\}$ give indeed realization for $p = 7$ system: UAA codes stopping sign, UAC codes cys and UCA and UCC code ser (using the standard short hand notation for RNA: s and amino-acids [A10]). The sequences formed from these DNA: s and corresponding amino-acids indeed realize $p = 7$ formal system as subsystem of $p = 127$ system. $p = 3$ formal system can be realized as UAA coding stopping sign and UAC coding cys. An interesting possibility is that this DNA-amino-acid subsystem has formed first in the biochemical evolution. For both $p = 3$ and $p = 7$ degenerate genetic codes one has $G + C/A + U = 1/2$. $G + C/A + U$ content varies in the range $(.7, 1.5)$ for insects and in the range $(1.17, 1.56)$ in the case of fish and for younger evolutionary forms A+U content is known to increase [I122].

3. The transition to "$p = M_{127}$ life" would require the addition of a rather large number of new "amino-acids" to the set of all possible amino-acid sequences consisting of 21 amino-acids whereas DNA triplets could be simply replaced with sequences of 21 DNA triplets. In the transition to $p = 127$ life tRNA triplets binding single amino-acid would be replaced by sequences of 21 tRNA triplets binding besides amino-acid sequences suitably modified amino-acid sequences in order to achieve maximal number of "amino-acids" at level $p = 127$. Also the modification of the translation system (in ribosomes) is required so that the "reading head" recognizes a sequence of 21 mRNA-triplets instead of single mRNA triplet. An interesting question is whether biochemistry might allow this kind of extension.

8.2.9 Summary

The simple model of abstraction has rather interesting connections with genetic code.

1. Combinatorial Hierarchy results as hierarchy of abstraction levels for statements or thoughts. Lowest level A_2 corresponds to the two possible values of Boolean variable and thoughts of

the level A_{n+1} correspond to statements about statements of level n that is Boolean maps $A_n \to A_2$. If the statement corresponding to sequence of zero bits is excluded the dimensions form a series of Mersenne numbers $3, 7, 127, M_{127}, ...$ Combinatorial Hierarchy is obtained also by considering the set of subsets with empty set excluded. The hypothesis that there is no upper bound for intelligence is equivalent with the hypothesis that these numbers are primes and that the numbers $p_n - 1$ in the sequence have the property that $p_n - 1$ divides $p_{n+1} - 1$. This implies that one obtains a hierarchy of Finite Fields $G(p_n, 1)$ and their multiplicative groups Z_{p_n-1} as well as coset groups $Z_{p_n-1}/Z_{p_{n-1}-1} = Z_{k_n}$, $k_n = (p_n - 1)/(p_{n-1} - 1)$.

2. There are $(p_n + 1)/2$ statements consistent with a given atomic statement at level n and the numbers come as $2, 4, 64, ...$ These statements are referred to as "DNA" type statements for obvious reasons. The dimensions k_n comes as $2, 3, 21, ...$ The hypothesis is that amino-acid type statements correspond to the statements of $Z_{k_n} \subset Z_{p_n-1}$ and can be regarded as general theorems whereas DNA type statements correspond to special cases of these theorems and are mapped to general theorems the mapping $x \to x^{p_{n-1}-1}$ at level n. At level n the genetic code corresponds to the non-unique choice of the $(p_n + 1)/2$ DNA type statements consistent with a given atomic statement in Z_{p_n-1}.

3. Biologically Genetic Code is determined by the competition between amino-acids: each amino-acid tries to maximize the number of DNA: s coding it (amino-acids are like politicians who are representatives of one truth and DNA: s are in the role of voters). The tendency favors $Z_{p_{n-1}-1}$ (Z_6) symmetry. The physically realized code can be understood as resulting from the symmetry breaking caused by the competition between the groups $Z_{p_{n-1}-1}$ (Z_6) acting on DNA: s associated with single amino-acid and factor groups of Z_{k_n} $(Z_{21} = Z_3 Z_7)$ transforming amino-acids to each other. Instead of finite dimensional representations of Lie groups the orbits of the cyclic groups Z_n are basic objects in the symmetry breaking mechanism.

4. At level n basic objects are k_{n-1}-plets of DNA: s of level $n - 1$ and sequences of same DNA units can in principle appear at all levels of the hierarchy. At the next $k = M_{127}$ level "DNA": s could therefore be regarded as sequences of 21 DNA triplets.

5. A hierarchy of increasingly complicated formal systems is predicted if one accepts the hypothesis. For the formal system of order n n: th level of the Combinatorial Hierarchy is the defining level in the sense that the number of "amino-acids" is maximal and equal k_n. Formal systems of order $n_1 < n$ are imbeddable into the formal system of order n. The formation of amino-acid sequences corresponds to the formation of theorems. For a formal system of order n amino-acid sequences realize only a small subset of all possible k_{n_1} truths at higher levels $n_1 > n$ of the Combinatorial Hierarchy in accordance with Gödel's theorem. One can also classify all possible bio-systems according to the value of n for the corresponding formal system. The Earthly life corresponds to $n = 3$ formal system and "life of order 4" would require the addition of rather large number of new "amino-acids" to the set of all possible amino-acid sequences consisting of 21 amino-acids whereas DNA triplets could be simply replaced with sequences of 21 DNA triplets. The realization of "$n = 4$ life" requires that tRNA triplets binding single amino-acid are replaced by sequences of 21 tRNA triplets binding besides amino-acid sequences suitably modified amino-acid sequences in order to achieve maximal number of "amino-acids" at level $n = 4$. Also the modification of the reading system (in ribosomes) is required so that the "reading head" recognizes a sequence of 21 mRNA triplets instead of single mRNA triplet.

6. An open problem relates to the precise role of DNA and proteins. The model of Boolean thoughts represented in terms of the cognitive fermion pairs leads to the correspondence between fermions and mind like space-time sheets and gives Combinatorial Hierarchy a special status. What comes in mind is that DNA provides a hardware representations of thoughts analogous to a computer memory. DNA molecules would be conscious selves representing 3 basic symbols in the mind of higher level self formed by DNA triplet. DNA sequences would be selves, experiencing DNA triplets as their sub-selves. Individual DNA molecules would represent sub-sub-selves so that DNA sequence would experience only the average of the experiences of individual DNA molecules.

7. It deserves to be noticed that I Ching claims that there are 64 fundamental mental states: could it be that these mental states correspond to all possible DNA triplet selves? It this interpretation is correct then Buddhist meditators would have achieved bio-feedback at DNA level! Genetic Code itself could be interpreted as a mapping of DNA selves to protein selves: this could be perhaps regarded as kind of mimicry or conscious abstraction process. Protein selves would represent theorem like abstractions of conscious thoughts represented by DNA selves.

8. It is known that cell numbers of different cell types in nervous, muscular, adipose, gonadic and homopoietic organs concentrate themselves around powers of two – 2^n, where n in the range $20 - 40$ [I136]: this can be understood if they result in n regularly occurring cell divisions. It might however be that the explanation of the regularity involves something much deeper. For instance, the cell types represent various n-bit sequences.

8.3 Combinatorial Hierarchy: two decades later

Combinatorial Hierarchy (CH) [A16, A25] is a hierarchy consisting of Mersenne integers $M(n) = M_{M(n-1)} = 2^{M(n-1)} - 1$ and starting from $M_1 = 2$. The first members of the hierarchy are given by $2, 3, 7, 127, M_{127} = 2^{127} - 1$ and are primes. The conjecture of Catalan is that the hierarchy continues to some finite prime. It was proposed by Peter Noyes and Ted Bastin that the first levels of hierarchy up to M_{127} are important physically and correspond to various interactions (see `http://tinyurl.com/hszo9wb`). I have proposed the levels of CH define a hierarchy of codes containing genetic code corresponding to M_7 and also memetic code assignable to M_{127} [K44].

Pierre Noyes and Ted Bastin proposed also an argument why CH contains only the levels mentioned above. This has not been part of TGD view about CH: instead of this argument I have considered the possibility that CH does not extend beyond M_{127}. With the inspiration coming from email discussion I tried to understand the argument stating that CH contains M_{127} as the highest level and ended up with a possible interpretation of the condition. Zero energy ontology (ZEO) and the representation of quantum Boolean statements $A \to B$ as fermionic parts of positive and negative energy parts of zero energy states is essential. This led to several interesting new results.

1. To my best understanding the original argument of Noyes does not allow M_{127} level whereas prime property allows. States at M_{127} level cannot be mapped to zero energy states at M_7 level. Allowing a wild association with Gödel's theorem, one could say that that there is hube number of truths at M_{127} level not realizable as theorems at M_7 level.

   A possible interpretation is that M_{127} level corresponds to next level in the abstraction hierarchy defined by CH and to the transition from embedding space level to the level of "world of classical worlds" (WCW) in TGD. The possible non-existence of higher levels (perhaps implied if $M_{M_{127}}$ is not prime) could be perhaps interpreted by saying that there is no "world of WCWs"!

2. Rather remarkably, for M_7, which corresponds to genetic code [K44], the inequality serving as consistency condition is saturated. One can say that any set of 64 statements consistent with a given atomic statement (1 bit fixed) at M_7 level can be represented in terms of 64 Boolean maps at M_3 level representable in terms of zero energy states. One obtains an explicit identification for the Boolean algebras involved in terms of spin and isospin states of fermions in TGD framework at level M_7 so that genetic code seems to be realized at the fundamental elementary particle level thanks to the dimension $D = 8$ of embedding space. Even more, the level M_{127} corresponding to memetic code emerges in the second quantization of fermions at M_7 level. Here color triplet property of quarks and color singletness of leptons and the identification of elementary particles as pairs of wormhole contacts are in essential role.

The conclusion would be that in TGD Universe genetic code and its memetic counterpart are realized at the level of fundamental particles. Already earlier I have ended up with alternative realizations at the level of dark nucleons and sequences of 3 dark nucleons [L28].

8.3.1 Summary of Combinatorial Hierarchy

I summarize first the basics of CH.

1. One considers the space algebra of Boolean statements of n bits which can be also extended to complex linear space -quantum Boolean algebra. One can give it linear structure as Z_2 algebra for binary coefficients with Z_2 sum having set theoretic interpretation. This linear space has some basis. That the coefficient field for linear structure is Z_2 does not seem to be absolutely essential. In TGD framework one considers the linear space defined by quantum Boolean algebra with qubit interpretation generated by fermionic oscillator operators: one operator for every bit.

2. One assigns to the linear n-D space the n^2-D space of linear maps of it to itself. One can also consider the space of maps of quantum Boolean algebra to itself and also require that this defines a Boolean homomorphism. Dimensions would be the same: only coefficient field would be different.

3. To CH level, which corresponds to Mersenne prime $M(n) = M_{M(n-1)}$ ($n = 2, 3, 7, 127, 2^{127} - 1, ...$) one assigns vector space with dimension

$$D(n-1) = [(M(n-1)+1)]^2 \ ,$$

and requires that the space formed by

$$D_1(n) = \frac{(M(n)+1))}{2}$$

bit sequences, which represent a subset of mutually consistent Boolean statements as subset of $M(n)+1$ bit sequences are representable as a subset of bit sequences with $D(n-1)$ bits. This demands

$$D_1(n) \leq D(n-1)$$

giving

$$\frac{M(n)+1)}{2} \leq [M(n-1)+1]^2 \ .$$

4. This criterion is satisfied for the primes of CH up to M_7 but not for M_{127}: $2^{127} - 1 > 128^2$ so that M_{127} should not included if I have understood the criterion correctly.

   For $M_7 = 2^7 - 1 = 127$ one obtains the condition $2^6 = 64 \leq 8 \times 8 = 64$ so that condition is saturated. Remarkably, 64 is the number of DNA codons!

5. The numbers of CH are also known as Catalan Mersenne numbers. Catalan Mersenne primes are special case of double Mersenne primes M_{M_n} (see `http://tinyurl.com/j4tqwch`). Catalan conjecture that Catalan Mersennes are primes up to some limit. After the first non-prime the remaining Catalan Mersenne numbers are necessarily composite. The known double Mersennes are given by M_{M_p}: $p = 2, 3, 5, 7$. No other cases are known. These primes are good candidates for labelling scaled up variants of say hadron physics. To my opinion Catalan criterion is more plausible.

6. Classical number fields are in key role in TGD [K96, K86, K40] and have dimensions $D = 1, 2, 4, 8$. Also CH involves these dimensions. $D(n-1) = M(n-1)+1$ giving dimensions $2, 4, 8$ for M_2, M_3, M_7. For M_{127} one would obtain $D = 128$, which does not correspond to any division algebra. This might relate to the above observation.

8.3.2 CH as a prediction of quantum TGD

In the following the interpretation of Boolean map in ZEO is proposed. Also it is shown that M_7 level allows a natural realization in terms of spin-isospin states of fermions and that M_{127} level is obtained in second quantization meaning going from the level of embedding space to the level of WCW.

Interpretation of the lower level Boolean map in terms of ZEO

One can ask, why one should have this kind of map? One interpretation is that the space of Boolean statements at given level is imbeddable to the space of quantum Boolean maps at previous level. Quantum Boolean maps would represent Boolean rules A→ B, "theorems" or "laws of physics".

1. In TGD framework the interpretation of CH would be as a hierarchy of statements about statements about... The number of statements about N statements is indeed 2^N. One statement corresponding to all bits equal to 0 (in set theoretic realization empty set) is thrown away so that one has $2^N - 1$ statements instead of 2^N.

2. ZEO means that physical states are pairs of states with opposite conserved quantum numbers: they correspond to physical events, which replace states as fundamental entities in ZEO. The fermionic parts of positive and negative energy parts of states would be pairs of many-fermion states allowing interpretation as elements of quantum Boolean algebra. Zero energy states themselves would correspond to pairs of these fermionic states and thus to "theorems" A→ B or maps from Boolean algebra to itself. The allowed statement pairs would satisfy fermion number conservation and conservation of various quantum numbers and would indeed represent laws of physics.

3. A possible interpretation of the map would be that the statements at given level $M(n+1)$ must be representable as theorems at previous level $M(n)$. For $M(n) > M_7 = 127$ this would not hold true anymore. Could this have some deep mathematical meaning as the wild association with Goedel's theorem suggests?

   In the model of genetic code and its generalizations [K44] I have proposed that each level of CH defines a maximal number of set of statements forming a set theoretic inclusion hierarchy and logical implication hierarchy: the number is 2^{n-1} for 2^n n-bit statements. For $M_7 = 127$ the number is 64, the number of DNA codons, which would thus have interpretation as axioms or "fundamental truths". In this case the representability would still hold and map would be bijection. At the next level one would have "memetic code" with 2^{126} codons representable as sequences of 21 DNA codons with stop codon included ($126 = 21 \times 6$). By the proposed criterion, at memetic level only vanishingly small subset of truths would be representable as theorems at genetic level.

Representation of M_7 level in TGD framework

Could the saturation for M_7 have some physical meaning? The maps would be from 8-D space to itself.

1. Bits can be represented in terms of spin and electroweak spin giving $2 \times 2 = 4$ states and embedding space-spinors ($H = M^4 \times CP_2$) of given H-chirality (quark or lepton like), given fermion number (fermion or antifermion) and physical helicity. If also unphysical helicities with fixed fermion number are allowed one would have $4 + 4 = 8$ states. The condition that helicity is physical would reduce the number of states by one half. This applies to both quarks and leptons since color is not spin like quantum number in TGD (colored states correspond to partial waves in CP_2).

2. What could be the interpretation for $2^7 - 1 = 127$ states containing as subset $n = 2^6$ states. Could $n = 2^6$ correspond to the number of states in the tensor product formed by pairs of 8 leptons and 8 antileptons allowed to have also unphysical polarizations? Same would apply to quarks. Allowing both quark-antiquark and lepton-antilepton type states one would have 128 states. The physicality condition for boson polarizations could drop the number of states

to 64. What the dropping of one state would correspond: to the dropping of $\nu_R - \overline{\nu}_R$ pair having no electroweak and color couplings perhaps?

One can imagine two alternative identifications for the two tensor factors.

(a) In TGD framework fundamental bosons correspond to fermion antifermion pairs with members at opposite throats of wormhole contact connecting two space-time sheets. Could the genetic code correspond to 64 elementary bosons with physical polarizations and the maps to those assigning to 8 fermions 8 antifermions?

(b) An alternative identification is suggested by ZEO. The tensor product of fermionic Boolean algebras at opposite boundaries of causal diamond (CD) would replace that at opposite wormhole throats. This would in accordance with the interpretation of zero energy states as statements $A \to B$ represented as Boolean maps.

Representation of M_{127} level in TGD framework

What about the physical interpretation of M_{127} level in TGD framework?

1. The first thing to observe is that physically $p = M_{127}$ corresponds in TGD to the p-adic prime p characterizing electron in p-adic mass calculations: Compton length is proportional to the p-adic length scale and thus proportional to $\sqrt{p}$. The remaining Mersenne primes correspond to completely super-astrophysical Compton lengths. Hence M_{127} has a very special role. The Mersenne primes $3, 7, 31, 127$ giving rise to double Mersenne primes correspond to extremely short p-adic length scales.

   Recall that the ratio of m_{CP_2}/m_e is approximately $m_{CP_2}/m_e = 2^{127/2}/\sqrt{5+x}$, where $x \in [0,1]$ characterizes the second order contribution to electron mass from p-adic mass calculations [K57]. The ratio of Planck mass to proton mass equals to $m_{Pl}/m_p = 1.307 \times 10^{19}$. For $x = 0$ this gives $m_{Pl}/m_{CP_2} = (m_p/m_e) \times 3.96 = 7.271 \times 10^3$, which is not far from $2^{13} \simeq 8.912 \times 10^3$. The value of 2^{13} is very attractive number theoretically and would be obtained for $x = .5$, again power of 2.

2. The states at this level should correspond to statements about statements at the lower level represented in terms of quark lepton state space as many-fermion states assignable to wormhole throat or several wormhole throats (elementary corresponds to two wormhole contants and 4 wormhole throats). The construction of infinite primes can be interpreted as a process of forming repeatedly statements about statements and the physical analog is repeated second quantization [K94].

   In the recent situation second quantization would correspond to the formation of many-fermion states at partonic 2-surfaces defined by the throats of wormhole contacts. This would automatically give rise to M_{127} states if one has 127 single fermion states to begin with.

   Physically this step would correspond to a step from the spinor modes of embedding space to the spinor modes of WCW identifiable as fermionic Fock states assignable to partonic 2-surfaces so that indeed a huge abstraction is in question. I have proposed that anyonic states could be this kind of states for large value of $h_{eff} = n \times h$ implying that the size of wormhole throat becomes nano-scopic [K73].

3. One has 127 boson states but how to obtain 127 (or $128 = 2^7$) single fermion states? Counting only spin and weak isospin gives $n = 8 + 8 = 2^4$ ($n = 4 + 4 = 2^3$) single fermion states if one allows (does not allow) also unphysical polarizations. The simplest option is that each single fermion state has 2^3 (2^4) additional states. The location of fermion at one of the 4 wormhole throat could give 4 additional degrees of freedom. This would leave 2 (4) additional states per fermion state still missing.

4. A good guess is that quark color realized as color partial waves comes in rescue and gives the needed states. Light quarks must move in color triplet states and leptons in singlet states. Thefore quarks have $3 \times 8 = 24$ modes and leptons 8 modes giving altogether 32 modes altogether. There are 4 wormhole throats so that $4 \times 32 = 128$ modes are obtained

and if right-handed neutrino is thrown out one has 127 states as required if no constraints on polarizations are posed. It therefore seems that TGD physics codes CH naturally at elementary particle level!

There is indeed a rich set of "vibrational" degrees of freedom giving also rise to color degrees of freedom. The symplectic group of $\Delta M^4_{\pm}$ assignable to either boundary of causal diamond (CD) defined as the intersection of future and past directed light-cones of M^4 with points replaced with CP_2 gives rise to products of S^2 and CP_2 partial waves. Besides this there is a conformal weight labelling the states correlating with $S^2 \times CP_2$ partial wave Light quarks massless before massivation by p-adic thermodynamics move in color partial waves and color triplets are obtained as the color excitations for them corresponding to higher conformal weights and having CP_2 mass as mass scale.

I have already earlier ended up with the proposal that genetic code is realized at the level of dark nuclear physics. Either the states of dark proton or sequence of 3 protons could be organized naturally states corresponding to 64 DNAs, 64 RNAs, 20 aminoacids, and 40 tRNAs and vertebrate genetic code follows from very simple assumption that opposite spins are paired [L2, K47] [L28] (see `http://tinyurl.com/jgfjlbe`). These findings suggest that genetic code and memetic code are also realized at the elementary particle level.

Acknowledgements: I am gratetul for James Bowery for raising the question about the possible relevance of CH for TGD.

8.4 Number theoretical models for genetic codes

The naïve thinking would suggest that the DNA-amino-acid correspondence is unique and same in the alien biology as in our biology. This is not the case. The notion N-particle leads to a model how N-hydrogen atoms define names for molecules and how molecules with conjugate names form especially stable bound states and how the same mechanism explains lock and key mechanism of bio-catalysis. The lock and key mechanism depends only weakly on chemistry and it is quite possible that several genetic codes are realized.

Hence the tRNA molecules mediating DNA-amino-acid correspondence could be different for various life-forms. The stability of various possible tRNA type molecules determining the code would be determined by the electromagnetic environment. Therefore one must take genetic code as a result of selection. The findings about the alien codes, if taken seriously, suggest also guesses about the origin of the genetic code.

The basic new result inspired by the attempt to identify the alien genetic code is the finding that both our and alien genetic codes factorize in a good approximation to a product codes associated with DNA doublets and singlets. This raises the question whether the factorization occurs also at the level of amino-acids. Could DNAs triplets have resulted as a symbiosis of singlets and doublets whereas amino-acids might have been developed via a symbiosis of 2 (3) molecules coded by 4 DNA singlets and 10 (7) molecules coded by 16 DNA doublets?

8.4.1 Three kinds of number theoretical models for the genetic code

TGD has led to three different number theoretic approaches concerning the understanding of the genetic code.

1. In [K44] the model of the genetic code based on the notion of Combinatorial Hierarchy is discussed. This approaches predicts at least one additional code that I have christened memetic code.

2. In [K28] a universal number theoretical code giving genetic code as a special case and based on the maximization of a number theoretic information measure was developed.

3. The model based on the assumption that genetic code has evolved from a product code is the one to be discussed in this chapter (see also the discussion in [**?**]).

Genetic codes as deformations of product codes

In this section number theoretical models based on the approximate factorization of the genetic code into product code formed by doublet and singlet codes are discussed. Product code as such predicts degeneracies approximately but fails at the level of detailed predictions for DNA-amino-acid correspondences. A volume preserving flow in discrete DNA space is needed to produce realistic DNA-amino-acid correspondences. This flow has the general tendency to cluster amino-acids to connected vertical stripes inside the 4-columns appearing as elements of the 4×4 code table, whose elements are labelled by the first two bases of DNA triplet. One can invent an information maximization principle providing a quantitative formulation for this tendency.

Genetic codes based on the maximization of number theoretic information measure

In the chapter [K28] an alternative number theoretic model for the ordinary genetic code and its variants is discussed. This model is based on very general number theoretic notions, in particular, number theoretical generalization of Shannon entropy, and must be regarded as the most convincing one of the three number theoretic models constructed hitherto. This model allows to identify ordinary genetic code and its variants as codes maximizing a unique number theoretic information measure. The model is also consistent with the idea that genetic code has evolved from a product of singlet and doublet codes.

The model predicts the number for "amino-acids" once the number n of "DNAs" is known as $N(n) + 2$, where $N(n)$ is the number of primes not larger than n. For 80 DNA triplets the prediction would be $24 = 3 \times 8$ rather than 23 amino-acids. Hence the two models for the genetic code would not be consistent.

Before making any hasty conclusions one should recall that the interpretation of the Crabwood circle as ASCII text involves considerable uncertainties. A modification of single special symbol or small letter to a symbol not appearing in the proposed interpretation of the Crabwood message would give 24 "amino-acids". For instance, the ASCII symbols for dot *resp.* comma are 00110100 *resp.* 01110100 and differ only by a single bit so that misinterpretation cannot be excluded.

This model of genetic code emerged much later than the model for alien genetic codes and is not discussed in this chapter.

8.4.2 Does amino-acid structure reflect the product structure of the code?

The exact A-G symmetry and the almost exact T-C symmetry of our genetic code supports approximate 2×10 structure such that 16 DNA doublets and 4 DNA singlets code for 10 *resp.* 2 "pre-amino-acids" which combine to form the real amino-acids. The 3×7 decomposition of the number 21 of amino-acids plus stopping sign suggests 3×7 decomposition of the genetic code. This decomposition is however not favored by the symmetries of the genetic code.

The coding of amino-acids involves tRNA binding with amino-acids and this means that the structure of amino-acids need not reflect the product structure of the genetic code and it might be that only the structure of tRNA reflects the product structure. Indeed, the identification of pre-amino-acids as DNA singlets or doublets dictated by RNA-DNA translation mechanism is strongly favored by the physical model for the evolution of the genetic code. With this identification triplet pre-amino-acids (DNA triplets) are simply composites of doublet and singlet pre-amino-acids (DNA doublets and singlets).

Despite this interpretation, the study of the amino-acid geometric structure is in order. It does not reveal any obvious structural 3×7-ness or 2×10-ness. One can however wonder whether this kind of structures might be present at more abstract level and present only in the interactions of tRNA and amino-acids.

1. 2×10 *product structure at amino-acid level*

2×10 decomposition for real amino-acids might approximately correspond to hydrophobic-hydrophilic dichotomy which plays a key role in the amino-acid chemistry. This correspondence

cannot be very precise since the number of the hydrophobic (-philic) amino-acids is 8 (12) rather than 10 (10). Of course, this is what one expects since the product symmetry is broken.

2. 3×7 *product structure at amino-acid level*

Aminocids can be classified into three groups. The first class contains 8 hydrophobic non-polar amino-acids: ala, val, leu, ile, pro, met, phe, trp, Second class consists of 7 hydrophilic polar amino-acids gly, ser, thr, cys, asp, glu, tyr. The third class consists of polar hydrophilic acidic amino-acids asp, glu and hydrophilic basic amino-acids lys, arg, his: 5 altogether.

Could these three classes correspond to the 3×7-ness?

1. First of all, the non-varying group contains almost(!) as a rule both the acidic carboxy group $COOH$ which tends to ionize to COO^- and basic aminegroup NH_3 which tends to ionize to NH_3^+. When carboxy or amine group is associated with the side group, the 2+3=5 acidic or basic polar amino-acids result. Thus the three-ness in standard sense corresponds to the difference for the total numbers of acidic and basic groups of the side chains: amino-acid side chain is either neutral and non-polar, neutral and polar, or charged. This leads to 8+7+5 decomposition and a slight breaking of three-ness.

2. One could however consider a modified definition in which one counts the numbers N_+ of basic and N_- of acidic groups of the *entire* amino-acid and uses the difference $N_+ - N_-$ to tell the net charge of the amino-acid. If this criterion is used, the first group contains one alien, proline. Proline differs from all other amino-acids in that the neutral group $H_3N^+ - COO^- - C - H$ group is replaced by a charged $HN - COO^- - C - H$ group. But this means nothing but replacing the basic group NH_3^+ with a non-basic NH. This implies also a net charge for proline. If net charge is taken as the characterizing property of the third group of amino-acids, proline belongs to it. Therefore first and second would group contain 7 amino-acids and the third group would contain 3 positively charged and 3 negatively charged amino-acids.

3. If one thinks that stopping sign formally corresponds to one additional amino-acid in the third group, one indeed has 7+7+7 decomposition. For some rare life-forms to be discussed later stopping sign codon ATC can code for both stopping sign and non-standard amino-acid pyrrolysine depending on context [I62]. Pyrrolysine, being a derivative of lysine, is basic so that in this case one would have 7+7+7 decomposition even without counting stopping sign formally as an amino-acid.

The 7-ness index labelling the amino-acids with the three groups should be some abstract property and it is impossible to make any conclusions on basis of the chemical formulae alone.

3. Is the product structure at the level of amino-acids really needed?

It has become clear that the product structure for amino-acids is not necessary.

1. The number theoretic model of the genetic code discussed in [K28] neither predicts nor requires the product structure for amino-acids but is consistent with the approximate product structure for codons.

2. In [**?**] a model for the evolution of the genetic code from a product code mapping RNAs to a subset of RNAs is studied. In this model the product structure at the level of coded RNAs is natural but there is no reason for it at the level of amino-acids which, according to the model, originally only catalyzed RNA→ RNA mapping but later replaced the coded RNAs in a kind of palace revolution.

8.4.3 Number theoretical model for the terrestrial genetic code

The study of the terrestrial genetic code allows to deduce the process leading to the breaking of the product symmetry and T-C symmetry. This process turns out to work as such also in case of alien codes.

Approximate reduction to a product code

The dependence of the amino-acid coded by DNA on the third codon of DNA triplet is weak and Crabwood message suggests that both doublet and triplet codes are realized. This inspires the guess that triplet code might have evolved as a fusion of doublet code and singlet codes.

This should be reflected in its structure. There are two options.

1. The decomposition $20 = 2 \times 10$ for real amino-acids suggest that singlet code maps four bases to 2 "pre-amino-acids" such that A and G resp. T and C are mapped to same pre-amino-acid, and 16 doublets to 10 "pre-amino-acids". The exact A-G symmetry and almost exact T-C symmetry of our genetic code support this interpretation.

2. The decomposition $21 = 3 \times 7$ for amino-acids plus stopping sign suggests that singlet code maps four bases to 3 "pre-amino-acids" and 16 doublets to 7 "pre-amino-acids". In the first approximation the triplet code would decompose to a product of doublet code and singlet code in the sense that 4 singlets are mapped to Z_3 and 16 doublets are mapped to Z_7 so that 21 different product states result. The decomposition of the statements consistent with some atomic statements suggests itself strongly. In the first approximation the triplet code would decompose to a product of doublet code and singlet code in the sense that 4 singlets are mapped to Z_3 and 16 doublets are mapped to Z_7 so that 21 different product states result. The problem of this option is that it predicts complete breaking of T-C symmetry and the breaking of the product symmetry should produce T-C symmetry. This looks two complicated.

Product code hypothesis is very strong since the degeneracies of the product code are products of the degeneracies for the composite codes so that the number n_{AB} of DNA triplets coding a given amino-acid having the product form "AB", to be referred as the degeneracy of the amino-acid, is given by the product

$$n_{AB} = n_A \times n_B$$

of the degeneracies of the "pre-amino-acids" A and B. Here A and B can refer to $(A, B) = (3, 7)$ or $(A, B) = (2, 10)$ respectively.

The number $N_{AB}(n)$ of amino-acids with given degeneracy n is given by the formula

$$N_{12}(n) = \sum_{n_1 \times n_2 = n} N_1(n_1) N_2(n_2) \ ,$$

where $N_1(n_1)$ resp. $N_2(n_2)$ is the number of pre-amino-acids with the degeneracy n_1 resp. n_2.

For 2×10 case singlet sector allows only single candidate for the code since the genetic code has exact A-G symmetry and almost exact T-C symmetry with respect to the last base. Thus A and G code for the first pre-amino-acid and T and C the second one. A breaking of the T-C symmetry is needed to obtain realistic code.

In 3×7 case singlet code would have following interpretation. Z_3 is identified as negations of 4 selected statements with 00 excluded. Statement and its negation are projected to this Z_3 representing negations with 00 excluded so that 11 must be projected to some other statement. The degeneracies of the code are unique: 2, 1, 1 since any change of the code changing this degeneracy spectrum implies that one degeneracy vanishes.

Same applies to Z_7 and 16 DNA doublets. Now 1111 is mapped to some statement in the set of negations. In this case the simplest coding is obtained by mapping 7 statements to their conjugates and the two remaining statements to different conjugate statements in the set of 7 statements. The resulting degeneracy structure is 2222233 and entropy is maximal for this code.

Our genetic code as result of symmetry breaking for 2×10 product code

As found, there are two cases to be considered: 3×7 T-C asymmetric and 2×10 T-C symmetric product code. The approximate T-C symmetry favors strongly 2×10 option and 3×7 will be considered only briefly in a separate subsection. On basis of degeneracies alone it is not possible to distinguish between these codes and 3×7 code was in fact the first guess for the product code.

n	1	2	3	4	6
N(prod)	0	12	0	4	4
N(real)	2	9	2	5	3

Table 8.6: The numbers $N(n)$ of amino-acids coded by n DNAs for unperturbed 2×10 product code and for the real genetic code for 2×10 option.

In case of 2×10 code the decomposition of 16 DNA doublets giving almost the degeneracies of our genetic code is (3322 111 111).

$$(2 \oplus 2) \times (3 \oplus 3 \oplus 2 \oplus 2 \oplus 6 \times 1)$$

This gives

It is important to notice that the multiplets appear as doubled pairs corresponding to A-G and T-C symmetries. One generalized amino-acid (which cannot correspond to stopping sign) is lacking and must result by a symmetry breaking in which one amino-acid in the code table is transformed to a new one not existing there. Alternatively three amino-acids are transformed to stopping signs.

It is easy to find the deformation yielding correct degeneracies by removing DNAs from the DNA-boxes defined by various values of degeneracies to other boxes and adding them to other boxes. The rule is simple: taking m DNAs from a box containing n DNAs creates a box with $n - m$ DNAs and annihilates one n-box:

$$N(n) \to N(n) - 1 \ , \quad and \ N(n-m) \to N(n-m) + 1 \ .$$

If one adds k of these DNAs to r-box one has

$$N(r) \to N(r) - 1 \ , \ \ N(r+k) \to N(r+k) + 1 \ .$$

The operation which is not allowed is taking the entire content of a DNA box defined by amino-acid and adding it to other boxes since this would mean that the amino-acid in question would not be coded by any DNA. Thus the number of boxes can only grow in this process.

Realistic degeneracies are obtained by a rather simple operation.

1. Take from one 6-plet two amino-acid and move the first of them to 2-plet to get $N(6) = 3$, $N(4) = 5$, $N(3) = 1 < 2$, $N(2) = 11 > 9$ and move the second one to hitherto non-existing singlet to get $N(1) = 1$.

2. Move one DNA from some doublet to second doublet to get triplet and singlet to get $N(1) = 2$, $N(2) = 9$ and $N(3) = 2$. This operation gives correct degeneracies only and it turns out that correct symmetry structure requires additional operations.

Failures of the product structure and the symmetry breaking as volume preserving flow in DNA space

A slightly broken product structure allows to understand the degeneracies of our genetic code relatively easily. It however leads also to wrong predictions at the level of DNA-amino-acid correspondence.

1. Exact product structure predicts that all 4-columns XYU, $U = A, G, T, C$ appearing as elements of the code table labeled by first and second bases of DNA triplet should have similar amino-acid structure. For 3×7 code the 4-column should have $AABC$ structure. This is not case. Almost all 4-columns have $AABB$ structure and there are also many $AAAA$ type 4-columns. For 2×10 code the prediction is that all 4-columns should have $AABB$ structure and this prediction breaks down only for $AAAA$ type 4-columns.

2. For 3×7 code a given amino-acid should be coded by DNA pairs of form (XYA, XYG), or DNA of form XYC or XYT. For 2×10 code a given amino-acid should be coded either by DNA pairs of form (XYA, XYG) or of form (XYC, XYT). This is not the case. A given amino-acid tends to appear as connected vertical stripes inside the elements of the 4×4 table (4-columns). For instance, all 4-columns of form $AAAA$ (A=leu, val, ser, pro, thr, ala, arg, gly) and 3-column ile break the prediction of the product code.

3. For 3×7 each 2n-plet formed by degenerate (XYA, XYG)-pairs is accompanied by n-plets of type XYT and XYC. In case of 2×10 2n-plet formed by (XYA, XYG)-pairs is accompanied always by an 2n-plet formed by (XYT, XYC) pairs. By studying the degeneracies of the codes one can get idea about how good these predictions are.

It seems that the breaking of the product symmetry tends to form connected vertical clusters of amino-acids inside a given element of the 4×4 code table but that one cannot regard stripes longer than 4 elements as connected structures. The 2×10 structure is favored by approximate T-C symmetry, and one can imagine that relatively simple flow in DNA space could yield the desired condensation of the amino-acids to form connected vertical stripes. The most general flow is just a permutation of DNAs and obviously preserves the degeneracies of various amino-acids. There are 64! different permutations but A-G and T-C symmetries reduce their number to 32!.

The idea about discrete volume preserving flow in DNA space can be made more precise. A-G and T-C gauge symmetries suggest the presence of a discrete symplectic structure. Perhaps one could regard 16×4 DNAs as 16 points of 4-dimensional discrete symplectic space so that the canonical symmetries of this space (volume preserving flows) acting now as permutations would be responsible for the exact A-G gauge invariance and approximate T-C gauge invariance. This brings in mind the canonical symmetries of CP_2 acting as $U(1)$ gauge transformations and acting as almost gauge symmetries of the Kähler action.

A natural guess is that the DNAs coding same amino-acid tend to be located at the same column of the 4×4 code table before the breaking of the product symmetry. If this is the case then only vertical flows need to be considered and A-G and T-C symmetries imply that their number is $8!^4$ corresponding to the four columns of the table.

The **Table 8.9** summarizes our genetic code. It is convenient to denote the rows consisting of A-G resp. T-C doublets by X_1 and X_2. For instance, A_1 corresponds to the highest row phe-phe, ser-ser, tr-tyr, cys-cys and G_2 to the row leu-leu, pro-pro, gln-gln, arg-arg.

1. The simplest hypothesis is 2×10 option is realized and that the flow permutes entire rows of the code table consisting of A-G and T-C doublets. From **Table 8.7** it is clear that there is a G-C symmetry with respect to the first nucleotide broken only in the third row. This kind of primordial self-conjugacy symmetry would not be totally surprising since first and third nucleotides are in a somewhat similar position.

2. There are 3 6-plets leu, ser, and arg, and it is easy to see that one cannot transform them to the required form in which all 6-plets are on A-G or T-C row alone using this kind of transformation. For instance, one could require that leu doublets correspond to T-C doublets before the symmetry breaking. This is achieved by permuting the G_1 row with the C_2 row. Since A_2 contains also ser-doublet, also ser must correspond to T-C type 6-plet, and since arg is contained by G_2 row, also arg must correspond to T-C type 6-plet. Thus there would be 4 T-C type 6-plets but the product code gives only 2 of them.

3. The only manner to proceed is to allow mixing of suitable 6-plet of A-G type and 4-plet of T-C type in the sense that A-G doublet from 6 is moved to T-C doublet inside 4-plet and T-C doublet in 4-plet is moved to A-G doublet inside 6-plet. The exchange of AG_2 (ser doublet) and TG_1 (trh-doublet) represents this kind of permutation.

The tables below summarize the three stages of the construction.

At the last stage the T-C symmetry breaking giving rise to bla-trp and ile-met doublets occurs.

1. thr 6-plet is transformed to 4-plet by replacing thr-thr in AC_2 by bla-trp. trp is the missing amino-acid.

	A	G	T	C	
A	phe	ser	tyr	cys	A
	phe	ser	tyr	cys	G
	leu	thr	stop	thr	T
	leu	thr	stop	thr	C
G	val	ala	glu	gly	T
	val	ala	glu	gly	C
	leu	pro	gln	arg	T
	leu	pro	gln	arg	C
T	ile	ser	asn	ser	A
	ile	ser	asn	ser	G
	met	thr	lys	arg	T
	met	thr	lys	arg	C
C	val	ala	asp	gly	A
	val	ala	asp	gly	G
	leu	pro	his	arg	A
	leu	pro	his	arg	G

Table 8.7: Code table before the flow inducing the breaking of the product symmetry.

	A	G	T	C	
A	phe	ser	tyr	cys	A
	phe	ser	tyr	cys	G
	leu	ser	stop	thr	T
	leu	ser	stop	thr	C
G	leu	pro	his	arg	A
	leu	pro	his	arg	G
	leu	pro	gln	arg	T
	leu	pro	gln	arg	C
T	ile	thr	asn	ser	A
	ile	thr	asn	ser	G
	met	thr	lys	arg	T
	met	thr	lys	arg	C
C	val	ala	asp	gly	A
	val	ala	asp	gly	G
	val	ala	glu	gly	T
	val	ala	glu	gly	C

Table 8.8: The code table after the action of the flow inducing the breaking of product symmetry.

	A	G	T	C	
A	phe	ser	tyr	cys	A
	phe	ser	tyr	cys	G
	leu	ser	stop	stop	T
	leu	ser	stop	trp	C
G	leu	pro	his	arg	A
	leu	pro	his	arg	G
	leu	pro	gln	arg	T
	leu	pro	gln	arg	C
T	ile	thr	asn	ser	A
	ile	thr	asn	ser	G
	ile	thr	lys	arg	T
	met	thr	lys	arg	C
C	val	ala	asp	gly	A
	val	ala	asp	gly	G
	val	ala	glu	gly	T
	val	ala	glu	gly	C

Table 8.9: The code table after the T-C symmetry breaking

2. TA_2 met-doublet is transformed to ile-met so that the realistic genetic code results.

One might argue that symmetry breaking permutations $G_1 - C_2$ and $AG_2 - TG_1$ should permute amino-acids with a similar chemical character. A similar constraint applies to T-C symmetry breaking. By studying the chemical structure of the amino-acids, one finds that this is satisfied to a high degree.

1. The permutations val-leu and ala-pro exchange amino-acids with non-polar (hydrophobic) sidegroups. The permutations glu-his and gly-arg exchange polar (hydrophilic) amino-acid with a polar amino-acid which is also basic. Ser and thr are both non-polar amino-acids.

2. ile and met are both non-polar so that ile$\rightarrow$ met replacement satisfies the condition.

3. The objection is that the side group for trp is non-polar but polar for thr. Interestingly, the code table decomposes to two connected regions corresponding to non-polar/polar side groups at the left/right such that the non-polar trp located inside the polar region is the only black sheep whereas thr naturally belongs to the polar region. As will be found trp is also otherwise singular case.

A working hypothesis worth of studying is that the symmetry breaking mechanism is universal and applies also to the capital letter code and even to the small letter + special symbol code in an appropriately generalized form. This hypothesis is highly predictive, and the fact that one can produce these codes using the product ansatz, the same "volume preserving flow", and T-C symmetry breaking, encourages to think that the picture has some truth in it.

The information maximization principle determining the "volume preserving flow"

The interaction between the DNA singlets and doublets is the physical explanation for the breaking of the product symmetry. This interaction involves two parts: the flow and T-C symmetry breaking. The flow is analogous to the formation of connected vertical stripes of amino-acids in DNA space: kind of condensation process in which different phases represented by amino-acids tend to condense to form regions consisting of at most 4-units of type XYU, $U = A, G, T, C$. Obviously this means continuity and thus also symmetry analogous to that emerging when (amino-acid) gases condense to a liquid state: the breaking of the product symmetry is the price paid for this additional symmetry. It turns out to be possible to formulate a variational principle consistent with the proposed flow in the direction of the columns of the code table and defining the dynamics of the condensation.

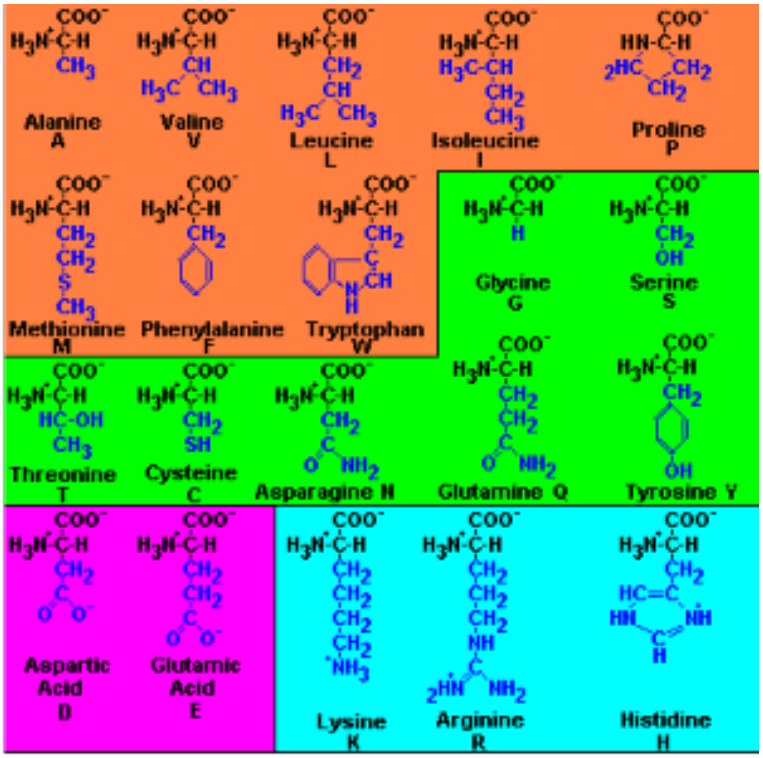


Figure 8.3: The chemical structure of amino-acids. The first group (ala, ...) corresponds to non-polar amino-acid side groups, the remaining amino-acids to polar side groups. The two lowest groups correspond to acidic (asp, glu) and basic side groups.

What this means that one can assign an information measure to the code table such that the volume preserving flow in question maximizes this information measure.

1. Information measure is assumed to be local in the sense that it decomposes into a sum of information measures associated with the elements C_{AB}, $A, B \in \{A, G, T, C\}$, of the 4×4 code table (elements are 4-element columns). In the physical analogy this means that the condensed droplets of various amino-acids can have at most the size of single 4-element column.

2. Consider the element C_{AB}. Let the multiplet associated with the amino-acid a_k contain $n(k, AB)$ amino-acids and let $i(k, AB)$ tell the number of the disjoint parts to which the amino-acidss a_k in the 4-plet AB split. The number of these disjoint multiplets can be $0, 1, 2$.

   Let the i: th region contain $n(k, AB, i)$ amino-acids a_k. The meaning of the equations

$$\sum_{i=1}^{i(k,AB)} n(a_k, AB, i) = n_k(AB) \quad ,$$

$$\sum_{AB} n_k(AB) = n_k \quad ,$$

$$\sum_k n_k = 64$$

   is obvious.

Assign to the i: th connected region containing $n(k, i, AB)$ identical amino-acids a_k probability

$$p(k,i,AB) = \frac{n(k,i,AB)}{64} \ ,$$

to the element AB the total probability

$$p(k,AB) = \sum_{i=1}^{i(k,A,B)} p(k,i,AB) \ ,$$

and to the entire table the probability

$$p_k = \sum_{AB} p(k,AB) = \frac{n(k,AB)}{64} \ .$$

The sum of the probabilities associated with various amino-acids satisfies

$$\sum_k p_k = 1 \ .$$

The information measure associated with amino-acid a_k element AB is defined as

$$I(k,AB) = \sum_{i=1}^{i(k,A,B)} p(k,i,AB) \times log[p(k,i,AB)] \ ,$$

Note that this number is non-positive always. The total information associated with the amino-acid a_k in code table is defined as

$$I(k) = \sum_{AB} I(k,AB) \ .$$

The total information of the code table is defined as the sum of the information measures associated with various amino-acids:

$$I = \sum_k I(k) \ .$$

This information measure is maximized (which means the minimization of the absolute value of the measure since one can speak of the minimization of entropy) by the vertical flow satisfying the previous constraints, and thus satisfying the constraints that the numbers a_k of various amino-acids are fixed and $A \leftrightarrow G$ and $T \leftrightarrow C$ symmetries are respected. There is a direct analogy with thermodynamical equilibrium with fixed particle numbers and symmetry. The equilibrium is characterized by the chemical potentials associated with the amino-acids. There is no temperature type parameter now.

The variational principle indeed favors the formation of vertically connected regions consisting of $n = 2, 3$ or 4 amino-acids. By construction the variational principle does not tell anything about larger regions. In particular, it is more favorable for 4 amino-acids in a given column (say ser in the second column of the table) to be contained by single element than by 2 elements since the information measure would be $-1/16log(1/16)$ for two disjoint doublets and $-1/16log(1/8)$ for singlet 4-plet in same element and thus smaller in absolute value. In the similar manner the AAAB decomposition of singlet element instead of say AABA is favored.

The deviations from the standard code as tests for the basic symmetries of the model

The deviations of the terrestrial genetic code from the standard code [I62] provide a testing ground for the postulated symmetries of the genetic code and might also help to deduce the alien codes.

The deviations from universality of the Start codon (coding for met) and stop codons are very rare. With two exceptions all known deviations from the standard code are located in the first and fourth columns of the code table. For the first exceptional case the codon is ATC in the third column and codes for both stopping sign and pyrrolysine, which is an exotic amino-acid. It is somewhat a matter of taste whether one should say that the universality of the third column is broken or not since, depending on context, ATC codes stopping sign or pyrrolysine.

Second exceptional case corresponds to the use of two stop codons to code amino-acids and this necessarily breaks the universality of the third column in T-C 2-subcolumns. The construction of the small letter code indeed forces to assume this kind of breaking of universality. No violations of the predicted A-G symmetry and the universality of the second column of the code table are known.

The deviations from the standard code [I62] provide valuable hints when one tries to deduce information about the alien codes.

1. Consider first the mitochondrial genes.
   i) Mitochondrial codon ACT from animals and micro–organisms (but not from plants) codes trp instead of stopping sign.
   ii) Most animal mitochondria use TAT to code met instead of ile.
   iii) Yeast mitochondria use GAX codons to code for thr instead of leu. This suggests that also in the case of the capital letter code the amino-acid coded 8 times is thr. In case of the small letter + special sign code the 13-fold degerate amino-acid could be thr.

2. The violations of the universality are very rare for nuclear genes. A few unicellular eukaryotes have been found that use one or two of three stop codons to code amino-acids instead. The use of two stop codons to code amino-acids necessarily violates the universality of the third column but need not break the universality for the embedding of amino-acid space to DNA space.

3. There are also two non-standard amino-acids: selenocysteine and pyrrolysine.

   (a) Selenocysteine is encoded by ACT (fourth column) coding stopping sign normally. Interestingly, ACT codes also stopping sign and the translation machinery is somehow able to discriminate when selenocysteine is coded instead of stop. This codon usage has been found in certain Archaea, eubacteria, and animals. This deviation means that the number of amino-acids is 21 or 20 depending on context. This conforms with the view that number 21 indeed has a deep number theoretical meaning and that one can regard stopping sign formally as amino-acid.

   (b) In one gene found in a member of the Archaea, exotic amino-acid pyrrolysine is coded by ATC, which corresponds to the lower stopping sign in the code table. This case represents the only deviation from universality of the third column of the code table but even in this case also stopping sign is coded. How the translation machinery knows whether to code pyrrolysine or to stop translation is not yet known. TGD would suggest that electromagnetic signalling mechanisms ("topological light rays") might be involved.

   The small variants of the letters K and V are lacking from small letter+special sign code. This might signal that the corresponding amino-acids are replaced by selenocystein and pyrrolysine represented by h and \ in the small letter code.

8.4.4 Capital letter code as a product code with broken T-C symmetry

What about capital letter code: does it also have approximate product structure? Product structure predicts that many degeneracies, in particular the largest degeneracies should be divisible by two. In case of 2×10 code all degeneracies are predicted to be divisible by two. This is not the case now as **Table 8.9** shows. One can however try to find a product code which is as near as possible to the real one.

The degeneracies 1111111234 for the doublet 2×10 representation differs from our genetic code in that 1111112233 is modified to 1111111234. These degeneracies would be the degeneracies most naturally associated with the 16 DNA doublet code with 10 "pre-amino-acids" possibly associated with plasmoid like life forms serving as messengers of the aliens.

The simplest option would be that this correspond to taking one doublet from second 2 and adding it to second 3 so that one additional singlet results. Unfortunately, the fact that stopping sign has degeneracy 7(8) excludes this option.

The 1111111234 decomposition predicts the following numbers for DNAs with various degeneracies. Also the corresponding numbers for capital letter code are included.

n	1	2	3	4	6
N(prod)	0	12	0	4	4
N(real)	2	9	2	5	3

Table 8.10: The numbers $N(n)$ of amino-acids coded by n DNAs for unperturbed 2×10 product code and for the real genetic code for 2×10 option.

	A	G	T	C	
A	phe	ser	tyr	cys	A
	phe	ser	tyr	cys	G
	leu	thr	stop	stop	T
	leu	thr	stop	stop	C
G	val	ala	glu	gly	T
	val	ala	glu	gly	C
	thr	stop	gln	arg	T
	thr	stop	gln	arg	C
T	ile	ser	asn	ser	A
	ile	ser	asn	ser	G
	met	thr	lys	arg	T
	met	thr	lys	arg	C
C	val	ser	asp	gly	A
	val	ser	asp	gly	G
	thr	pro	his	arg	A
	thr	pro	his	arg	G

Table 8.11: Capital letter code table before the flow

The following process gives the degeneracies of the OPpose code.

1. Take one DNA from second 8-plet and add it to 6-plet to get two 7-plets so that one has $N(7) = 2$ and $N(6) = 1 > 0$.

2. Change one DNA in 6-plet to the DNA which does not exist in the table to get $N(6) = 0$, $N(5) = 1$, $N(1) = 1$. The non-existing DNA is generated in essentially the same manner also in case of our code.

3. One can transform 7 2-plets into 2 3-plets, 4-plet and 4 singlets as follows. Take from two doublets one DNA and move them to third doublet to get $N(1) = 3 < 5$, $N(2) = 11 > 7$, and $N(4) = 3$. There are four superfluous doublets remaining and forming pairs. For each pair take DNA from one doublet and move it to second one to get $N(1) = 5$, $N(2) = 7$ and $N(3) = 2$.

Assuming that the decomposition of DNA doublets is obtained from that for our code in the proposed manner and that the same flow induces T-C symmetric part of the breaking of the product symmetry, one can fix the DNA-amino-acid correspondence highly uniquely for the capital latter code. The unbroken code contains two octets. Since for yeast mitochondria both GA and TA columns code for thr, the guess is that the second octet corresponds to thr. The second octet must be ser from the product symmetry. The requirement that the code table resembles as much as possible the code table of our genetic code leads to the following working hypothesis for the code table before symmetry breaking.

T-C symmetry breaking can be understood as follows.

1. Take one DNA from second 8-plet (ser or thr and add it to 6-plet representing stopping sign

	A	G	T	C	
A	phe	ser	tyr	cys	A
	phe	ser	tyr	cys	G
	leu	ser	stop	stop	T
	leu	ser	stop	stop	C
G	thr	pro	his	arg	A
	thr	pro	his	arg	G
	thr	stop	gln	arg	T
	thr	stop	gln	arg	C
T	ile	thr	asn	ser	A
	ile	thr	asn	ser	G
	met	thr	lys	arg	T
	met	thr	lys	arg	C
C	val	ser	asp	gly	A
	val	ser	asp	gly	G
	val	ala	glu	gly	T
	val	ala	glu	gly	C

Table 8.12: Capital letter code table after the flow

	A	G	T	C	
A	phe	ser	tyr	cys	A
	phe	ser	tyr	cys	G
	phe	ser	stop	stop	T
	leu	ser	stop	trp	C
G	thr	pro	his	arg	A
	thr	pro	his	arg	G
	thr	stop	gln	arg	T
	thr	stop	gln	arg	C
T	ile	thr	asn	ser	A
	ile	thr	asn	ser	G
	ile	thr	lys	arg	T
	met	stop	lys	stop	C
C	val	ser	asp	gly	A
	val	ser	asp	gly	G
	val	asp	asp	gly	T
	val	ala	glu	gly	C

Table 8.13: Capital letter code table after the T-C symmetry breaking

to get two 7-plets so that one has $N(7) = 2$ and $N(6) = 1 > 0$. Thr is chosen in the sequel for definiteness and corresponds to TGC.

2. Change one DNA in thr 6-plet to the DNA which does not exist in the table to get $N(6) = 0$, $N(5) = 1$, $N(1) = 1$. The non-existing DNA is generated in essentially the same manner also in case of our code. stop at ACT is transformed to trp as so that trp is in the same position as in our genetic code.

3. What one must do is to transform 7 2-plets into 2 3-plets, 4-plet and 4 singlets. This is achieved in the following manner.

   (a) Take from two T-C doublets one DNA and move them to a third doublet to get $N(1) = 3 < 5$, $N(2) = 11 > 7$, and $N(4) = 3$. For instance, this is achieved by transforming glu and ala to asp. The value of information measure decreases by $log(64/27)$ in this process. There are also many other ways to do this.

   (b) There are four superfluous doublets remaining and forming pairs. For each pair take DNA from one doublet and move it to second one to get $N(1) = 5$, $N(2) = 7$ and $N(3) = 2$. More concretely $(AA)_2$ leu doublet is transformed to phe-leu, and $(TA)_2$ met-doublet is transformed to ile-met so that correct degeneracies result and the information measure increases in these processes by $2 \times log(27/16)$ which is larger than $log(64/27)$ so that the net increase of the information measure is positive in the entire process.

The process is not obviously completely unique but the proposed choice is favored because the small latter+special sign code can be obtained as a small deformation of this code.

8.4.5 T-C symmetric models for small letter plus special symbol code

One can apply T-C symmetric product model with symmetry breaking also to the code candidates involving small letters. There are three candidates for these codes.

1. The 4×17 code with 18 amino-acids involving only small letters with h interpreted as stoppping sign: this code makes sense for Oppose option only and since the expressive power is not maximal, it will not be discussed in the sequel.

2. $4 \times (16 + 4)$ code with 23 generalized amino-acids (\, h, and special symbols $!, \&, .$ are interpreted as belonging to the extended family of amino-acids).

3. The $4 \times (16 + 4)$ code with 20 amino-acids (\ and h are interpreted now as amino-acids). This code results from the code with 23 generalized amino-acids by assuming that the DNAs coding for $!, \&$ and period code for the stopping sign.

The candidates 2) and 3) appear as Oppose and OPpose options.

The nature of silicon modification

The product model for the genetic codes suggests an interpretation of the small letter codes. The Chilbolton message tells that also silicon is fundamental for the alien life at DNA level so that one can consider the possibility that one of the DNA and RNA doublets is modified by an addition of something containing silicon to give an additional doublet.

For $(4+16) \times 4$ code four additional doublets must be present. If some base of DNA suffers a modification, it suffers the modification also if it appears in RNA triplet at the same position, and this in turn implies that also the conjugate of the DNA base suffers modification so that 32 additional triplets are generated. Thus the modified base of DNA cannot appear in RNA and vice versa. DNA bases (A, G, T, C) correspond to RNA bases (U, C, A, G). Since the T of DNA corresponds to the U of RNA, there is only one possibility. The modified base is T for DNA and U for RNA, and the T_S of DNA must correspond to U_S of RNA rather than A_S. The simplest possibility is that the doublets of form XT have doubled by the silicon modification of the second T to XT_S. Also $T_S X$ type modification is in principle possible but the construction of the code favors the XT_S option (in this case code the table gets a fifth column whereas for $T_S X$ gives rise to a fifth row).

n	1	2	3	4	5	6	8	9	10	12	13
N	0	16	0	4	0	2	0	0	2	0	0
N	10(9)	4(5)	0	3	2(3)	3(2)	0	1	0	0	1

Table 8.14: The numbers $N(n)$ of amino-acids coded by n DNAs for code containing small letters and special symbols for 2×12 option. Both OPpose and Oppose options are included.

2×12 product model for the small letter plus special symbol code with 80 generalized DNAs and 23 amino-acids

The optimal candidate for the code involving 64+16 generalized DNAs involves 20+3 generalized amino-acids. There are two options corresponding to the decompositions $24 = 3 \times 8$ and $24 = 2 \times 12$. The assumption that small letter plus special sign code follows from the capital letter code as extension favors 2×12 option. 2×12 option for the small letter + special sign code allows highly unique model since one can assume that the code results as a simple extension of the capital letter code and is obtained by the same symmetry breaking procedure as the capital letter code and terrestrial genetic codes. The discussion below is restricted to OPpose option.

The first step is to deduce the composition in the set of $4 + 16$ DNA doublets defining the product code. The only working option has the decomposition 111111112235, which corresponds to the decomposition

$$20 \times (2 \oplus 2) = (5 \oplus 3 \oplus 2 \oplus 2 \oplus 8 \times 1) \times (2 \oplus 2) \quad .$$

This gives **Table 8.14** for the degeneracies.

The breaking of the product symmetry looks large but it turns out that the code can be obtained as a relatively small deformation and extension of the capital letter code.

The first things to observe about the code are following.

1. Comparing the decomposition 111111112235 with the corresponding decomposition 1111111234 for the capital letter code, one can guess that the small letter code is obtained from the capital letter code by the following process in the set of 4 exotic RNA-doublets. Decompose the four exotic RNAs to $(2 \oplus 1 \oplus 1) \times (2 \oplus 2)$ such that $2 \times (2 \oplus 2)$ codes for exotic and ordinary amino-acid quartet. Since trp is lacking from capital letter code before symmetry breaking, one can assume that trp is the ordinary amino-acid. Since the exotic amino-acid "period" appears five times, the second 4-plet must code for "period". The two doublets must code for exotic doublets & and ! which reduce to singlets after symmetry breaking. Two exotic doublets fuse with the two octets of the capital letter code to code for two decouplets and must therefore code for the ordinary amino-acids ser and thr. Thus the code table without symmetry breaking looks very much like capital letter code table.

2. The modification $XT \to XT_S$ implies that code table gets fifth column. Only this option allows to generalize in non-trivial manner the flow and allows to see trp 4-plets as being consistent with product code.

3. Terrestrial codes contain two exotic amino-acids scys and plys. The fact that the small letter + special sign code contains the symbols h and \ with ASCII number larger than 64 not appearing in the capital letter code is taken as a suggestion that the corresponding amino-acids are exotic. A natural working hypothesis is cys is replaced with scys and lys with plys. Needless to add, this hypothesis must be taken with a grain of salt.

1. Product code before flow

The code table before the action of the flow and T-C symmetry breaking looks like follows. The code table obviously resembles capital letter code table to a very high degree and satisfies all the constraints resulting from the A-G and T-C symmetries and product structure of the code.

2. The action of the flow

	A	G	T	C	T_S	
A	phe	ser	tyr	scys	.	A
	phe	ser	tyr	scys	.	G
	leu	thr	stop	stop	thr	T
	leu	thr	stop	stop	thr	C
G	val	ala	glu	gly	!	T
	val	ala	glu	gly	!	C
	thr	stop	gln	arg	trp	T
	thr	stop	gln	arg	trp	C
T	ile	ser	asn	ser	.	A
	ile	ser	asn	ser	.	G
	met	thr	plys	arg	&	T
	met	thr	plys	arg	&	C
C	val	ser	asp	scys	ser	A
	val	ser	asp	scys	ser	G
	thr	pro	his	arg	trp	A
	thr	pro	his	arg	trp	G

Table 8.15: Small letter special sign product code before flow and T-C symmetry breaking.

	A	G	T	C	T_S	
A	phe	ser	tyr	scys	.	A
	phe	ser	tyr	scys	.	G
	leu	ser	stop	stop	thr	T
	leu	ser	stop	stop	thr	C
G	thr	pro	his	arg	trp	A
	thr	pro	his	arg	trp	G
	thr	stop	gln	arg	trp	T
	thr	stop	gln	arg	trp	C
T	ile	thr	asn	ser	.	A
	ile	thr	asn	ser	.	G
	met	thr	plys	arg	&	T
	met	thr	plys	arg	&	C
C	val	ser	asp	scys	ser	A
	val	ser	asp	scys	ser	G
	val	ala	glu	gly	!	T
	val	ala	glu	gly	!	C

Table 8.16: Small-letter special sign genetic code after the flow and before T-C symmetry breaking.

	A	G	T	C	T_S	
A	phe	ser	tyr	cys→ scys	.	A
	phe	ser	tyr	cys→scys	.	G
	phe	ser	stop	stop→trp	thr	T
	leu	ser	stop	trp	thr	C
G	thr	pro	his	arg	trp	A
	thr	pro	his	arg	trp	G
	thr	stop	gln→phe	arg	trp	T
	thr	stop	gln	arg	trp	C
T	ile	thr	asn	ser	.	A
	ile	thr	asn	ser	.	G
	ile	thr	lys→ ile	arg	.	T
	met	stop	lys→ plys	arg	&	C
C	val→ ser	ser	asp	gly→scys	ser	A
	val→ser	ser	asp	gly→scys	ser	G
	val→ ser	asp	asp	gly→asp	asp	T
	val	ala	glu	gly	!	C

Table 8.17: Small letter special sign genetic code resulting from T-C symmetry breaking. The replacements $X \to Y$ tell how the code in the sector of ordinary DNAs is obtained from the capital letter code.

3. T-C symmetry breaking

The basic assumptions are that the G-column of the code is universal for the alien code just as it is universal for the terrestrial codes, and that the code table resembles maximally to our code table and capital letter code table.

1. One must transform the two 10s (thr and ser) to 13 and 9. The clue to the symmetry breaking mechanism comes from the finding that one must be able to generate as many as 10 singlets. Hard trial and error work teaches that one cannot get these singlets unless one allows $10 + 4 \to 13 + 1$ mechanism for producing one of the singlets. The transformation of val-val-val-val to ser-ser-ser-val is the only candidate for this transformation and gives $N(4) = 3$ (scys, period, trp) and $N(1) = 1$.

   The thr is the second 10-plet and the transformation of TTC-thr to stop is the only possibility if the universality of the G column in alien sector is assumed. The transformation of $(AC)_2$ stop-stop column to trp-trp implies maximal resemblance with our genetic code, and one obtains $N(13) = N(9) = 1$ (thr, ser), $N(6) = 2$ (arg, trp), $N(5) = 1 < 5$ (stop) and $N(4) = 2 < 3$ (scys, period).

2. The remaining transformations must produce $N(1) = 10 > 1$, $N(2) = 4$, $N(4) = 3 > 2$, $N(5) = 2 > 1$, $N(6) = 3 > 2$ by acting on the T-C type doublets only and thus generating a breaking of T-C symmetry. The first step is to replace & in the $(TT_S)_2$ by "period" to get $N(5) = 2$, $N(4) = 1$, $N(1) = 2$. What one must create by the splitting all the remaining T-C doublets so that 2 4-plets and 1 6-plet as extension of A-G type doublets results. The choice of the A-G type doublets is not unique but the requirement that the code table resembles maximally the code table of the capital letter code fixes the choice of A-G type doublets extended to 4-plets to be AA_1 (phe), $(TT)_1$ (ile) and the A-G type doublet extend to 6-plet to be CT_1 (asp). **Table 8.17** summarizes one possible code table satisfying these constraints. For comparison also the table for capital letter code is given.

Product model for the small letter code with 20 amino-acids and 80 generalized DNAs

The number theoretical model generalizes for the codes defined by 64 ordinary DNAs + 16 DNAs of form XT_SY and assuming that besides 20 amino-acids there are 3 additional modified amino-

acids. A small letter-special symbol code with 80 DNAs and 20 amino-acids is obtained from 23-amino-acid code by assuming that the exotic DNAs coding for special signs !, & and period code for stopping sign and the previous construction for 2×12 code works as such. Oppose option with 64 DNAs (special signs being not interpreted as belonging to the code) and 18 amino-acids is in conflict with the requirement of a maximal expressive power. My personal conviction is that this option can be safely forgotten.

Why the numbers 64 and 80?

The dark matter hierarchy based on the hierarchy of increasing values of Planck constant predicts that the entire universe is a macroscopic quantum system and elementary particles have a hierarchy of zoomed up variants with arbitrarily large Compton length (proportional to $\hbar$) [K38]. Dark matter should be especially important for living matter and life should therefore involve fundamental physics in an essential manner rather than emerge at some very high level of complexity. Hence one can ask whether the numbers 64 and 80 for the codons of the two codes could reflect basic facts about fundamental physics in TGD Universe. The following numerological argument based on detailed counting of particle states encourages to take this idea half-seriously at least.

1. Gravitons and more general stringy states are not counted since they correspond to bound states of fermions and bosons connected by flux tubes. Color is counted neither since it corresponds to CP_2 partial wave and is not spin like degree of freedom in TGD framework. Family replication phenomenon has a topological explanation and is counted neither. This leaves only spinorial degrees of freedom which according to TGD inspired theory of consciousness are responsible for Boolean representations using fermionic Fock states. The natural guess is that these fermionic degrees of freedom might relate to the genetic code or genetic code might represent them.

2. TGD predicts in purely spinorial degrees of freedom 8 lepton states (lepton and anti-lepton both having 4 states due to spin and electro-weak isospin). Also phase conjugates of these states are predicted so that 8+8=16 states are obtained. The number of spinor states is same in the quark sector. This gives 16+16=32 states altogether.

3. Bosons are identifiable as tiny wormhole contacts carrying fermion and anti-fermion numbers at the light-like wormhole throats. Essentially lepto-antilepton and quark-antiquark pairs or their superpositions are in question. $(2 + 1) \times (3 + 1) = 12$ leptonic and 12 quark like bosons with spin and electro-weak isospin equal to 1 or 0 (only two massless spin states are possible). Together with phase conjugates this makes 24+24= 48 states. 24 of them correspond to ordinary electro-weak gauge bosons and Higgs and the remaining 24 are exotic bosons with charge matrices orthogonal to the charge matrices of electro-weak gauge bosons. For exotic counterparts of W bosons and Higgs the sign of the coupling to quarks is opposite. For photon and Z^0 also the relative magnitudes of the couplings to quarks much change. The total number of bosonic states is 48 and the number of all particle states in this sense is 48+16+16=80. If quarks are dropped from consideration the number is 64.

4. The numerological question is whether the 64 ordinary genetic codons are in some deeper sense in one-one correspondence with 48 color singlet gauge bosons and 16 lepton states and the 80 codons of the extended code in one-one correspondence with all states constructed in this manner.

8.4.6 Embedding of the amino-acid space into DNA space and the universal part of the genetic code

The concrete geometric formulation for the symmetries is based on the embedding of 20+1 generalized amino-acids to the space of 64 DNAs. Obviously, the amino-acids are coded by the DNAs to which they are mapped by this embedding. There is indeed an embedding of 20 amino-acids plus stopping sign with 2×10 structure to the set of 64 DNA triplets which have 4×16 structure. 2 is imbedded into 4 which corresponds to the 4 last bases of DNA and 10 into 16 which corresponds to 16 pairs of first two bases of DNA. The lacking amino-acid is embedded as a kind of outsider

for 64 DNA codes. In case of 80 DNA-24 generalized amino-acid code this embedding is replaced with the embedding of 2 amino-acids to 4 and 12 to $16 + 2$ structure.

This kind of embedding would be regarded in the language of mathematician as a a discrete bundle structure which is also singular in the sense that the fiber above a given base point does not always have the same number of points. The 10×2 and 16×4 compositions suggest the interpretation as the embedding of the space formed by 10 points of 2-D space-time to the space formed formed by 16 points of 4-D space-time. Analogous interpretation applies also in the case of the extended codes.

The interpretation conforms with the general idea that DNA represents a plan and involves intentionality and time dimension somehow. The amino-acids coded by several DNAs correspond to surfaces for several time values correspond to the same spatial point represented by amino-acid. The set of DNAs coding single amino-acid brings in mind the notion of "association sequence" defined as a disjoint union of space-like 3-surfaces with time-like separations and possible by the classical non-determinism of the Kähler action absolutely crucial for understanding consciousness in TGD framework [K59]. The number of DNAs coding the amino-acid would measure the degree of intentionality involved with it: each DNA associated with the amino-acid would symbolize one step in a plan. Some of alien amino-acids would be highly intentional: the degeneracies can be as high as 13 to be compared to the maximal degeneracy of 6 for our code!

Consider now in more detail this structure.

1. Exact A-G gauge symmetry implies that the pairs (XYA, XYG) form fibers and one can choose freely XYA or XYG to represent the amino-acid. In case of T-C symmetry symmetry breaking can select either XYT or XYC uniquely as a representative of the amino-acid.

2. For amino-acid coded by two DNAs only the identification of the amino-acid is unique apart from the possible gauge symmetry. For $n > 2$-plets the identification involves non-uniqueness.

3. The requirement that the embedding of amino-acids to DNA space is universal allows to fix identification uniquely in case of $n > 2$-plets. It turns out that one can assume universal embedding to make sense for both terrestrial and alien codes (if the replacements cys$\rightarrow$ scys and lys $\rightarrow$ plys possibly occurring for the small letter + special sign code are appropriately interpreted). This assumption fixes the embedding highly uniquely and the only uncertainties relate to the T-C symmetry breaking. The possibility to choose the universal part of the code table to be the same for all codes, suggests that the proposed model catches something essential. It is also difficult to imagine that a randomly generated ASCII message could allow interpretation in terms of genetic codes having so high symmetry properties and common construction principles. **Table 8.18** summarizes the universal part of the genetic code resulting from the embedding of the amino-acid space to DNA space. Also small letter code is included.

8.4.7 Summary

To sum up, both the terrestrial and hypothetic alien genetic codes can be constructed from the A-G and T-C symmetric product codes by assuming a breaking of both product– and T-C symmetries. Product structure and symmetries suggests strongly that genetic codes have evolved as a fusion of much simpler doublet and singlet codes. Hydrophilic-hydrophobic dichotomy is a good candidate for the dichotomy implied by the 2×10 product structure. The assumption that the breaking of the product symmetry induced by the "volume preserving flow" in DNA space tending to cluster amino-acids in the vertical direction of the code table is universal, and the hypothesis that the embedding of the amino-acid space to the DNA space is universal, together fix the identification of the codes highly uniquely.

The small letter-special symbol code with 80 DNAs and 23 amino-acids is favored because it maximizes both the information content and the expressive power of the code. The degenerate code with 80 DNAs and 20 amino-acids is obtained from the 23-amino-acid code by assuming that the exotic DNAs coding for special signs !, & and period code for stopping sign. To my own opinion

	A	G	T	C	T_S	
A	phe	ser	tyr	cys (scys)	.	A
						G
						T
	leu		stop	trp		C
G		pro	his	arg		A
						G
						T
			gln			C
T	ile	thr	asn			A
						G
						T
	met	thr	lys (plys)		&	C
C			asp			A
						G
						T
	val	ala	glu	gly	!	C

Table 8.18: A possible embedding of the amino-acid space to the DNA space. The gauge choice XYA allowed by A-G gauge invariance of the last codon is made. The identification is same for both our code, capital letter code, and small letter plus special sign code. There is some uncertainty related to the T-C symmetry breaking.

the OPpose option for the small letter code with 80 DNAs and 23 amino-acids is the most plausible alternative.

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8.5 Genes, Memes, And Universal Language

In TGD framework the notion of magnetic body plays a key role in the understanding of bio-systems and communications between magnetic and material body could be based on memetic code words. Magnetic body is the fundamental intentional agent is in the same relation to the material body as memetic code to the genetic code and computer software to the hardware or the manual to the electronic instrument. Hence there is a strong temptation to believe that memetic codewords represented as field patterns of duration.1 seconds is associated with the communications between magnetic body and brain.

For instance, the fact that 10 Hz is basic hippocampal frequency suggests that declarative memories could be based on time mirror mechanism (see **Fig.** `http://tgdtheory.fi/appfigures/timemirror.jpg` or **Fig. ??** in the appendix of this book) with negative energy sig-

nal from the magnetic body of the geometric future reflected from the brain of the geometric past as a positive energy signal back to the magnetic body of the geometric future. Classical communications could utilize memetic code using pulse or frequency coding. These field patterns could also define shared mental images. For instance, sequences of the memes represented as field patterns could activate intronic memes, which in turn would activate genes.

8.5.1 Genes-Memes, Biology-Culture, Hardware-Software?

The reports of the Public Consortium about human genome in Nature, Feb 15, 2001 [I79] and of Celera Genomics in Science of Feb 16th, 2001, [I109] demonstrated that the amount of human genome differs relatively little from those of lower organisms: we have only about 30, 000 genes, little more than twice the number 13, 601 of genes for fruit fly. This paradoxical finding strongly supports the view that our genome is not solely responsible for what we are and that the intronic portion of DNA (only about 1 per cent codes of human DNA codes or amino-acid sequences), is not " junk DNA", but contains important biological information and expresses it non-chemically.

In TGD Universe introns would express memes as the classical field patterns associated with MEs ("topological light rays") responsible for the basic expressions of language understood in an extremely general sense. This language includes body language and even cellular signalling, and could quite well make possible (not necessarily conscious) interspecies communications based on the memes and genes expressed by both communicating species and forming a common portion of grammar and vocabulary. All eukaryotes (cells with nuclei), even bacteria, would possess part of the memes of this universal language. The memetic code word is predicted to consist of a sequence of 21 DNA triplets and carries 126 bits of information instead of 6 bits of genetic code. Of course, also genes could be expressed in terms of MEs and could define a lower level language possessed also by prokaryotes.

The actual role of DNA could be understood using a computer analogy. Memes represent the program modules written using the programming language defined by the memetic code and realized in terms of the field patterns associated with MEs. Genes represent the lower level programs coding for the necessary hardware. System builds only the hardware needed, that is cell expresses only a small fraction of the genome. For neurons this fraction is known to be highest. DNA engineering requires besides the addition of the new programs (memes, introns) also the insertion of the necessary hardware (new genes). Memes and corresponding genes should have very intimate relationship. In this conceptual framework the standard view is wrong since it identifies the build-up of a new hardware as the sole activity at the DNA level. This would be like identifying the addition of a net card to a computer as the fundamental activity related with computers.

8.5.2 Pulse And Frequency Representations Of The Genetic And Memetic Code Words

The most general form of p-adic length scale hypothesis implies that each p-adic prime $p \simeq 2^k$, k integer, defines a hierarchy of physically favored p-adic time scales given by $T_p(n) = p^{(n-1)/2}T_p \equiv T(n,k)$, $T_p = \sqrt{p}T_{CP_2}$, where T_{CP_2} is the so called CP_2 time scale about 10^4 Planck times. The most general assumption assigns to any prime $p \simeq 2^k$, k integer, a hierarchy of cognitive codes with codeword having a duration equal to n-ary p-adic time scale $T_p(n)$ such that the number of bits is factor k_1 of k.

Code words could be realized either as k_1 first harmonics of the fundamental frequency $f_p(n) = 1/T_p(n)$ or as temporal sequences of k_1 bits of duration $\tau = T_p(n)/k_1$ represented as pulses of maximal duration τ. These representations will be referred to as frequency and pulse representations respectively. EEG represents a good candidate for frequency representation.

1. Pulse representations, scalar wave pulses, and transformation of intentions to actions

Pulse representations could be realized in terms of scalar wave pulses predicted by TGD and claimed to exist already by Tesla [K37]. Scalar wave pulses can be visualized as capacitors moving with light velocity and carrying longitudinal essentially constant electric field. If charged particles of matter end up temporarily to the space-time sheets of the scalar wave pulse, they are accelerated without dissipation and generate negative energy "acceleration radiation" rather than brehmstrahlung at harmonics of the frequency determined by the duration of the scalar wave pulse.

Under obvious conditions on the duration of the scalar wave pulse the negative energy radiation can be amplified to positive energy radiation by time mirror mechanism.

Quite generally, the generation of scalar wave pulses seems to provide a basic mechanism generating negative energy radiation (phase conjugate radiation) and nerve pulses are probably accompanied by scalar wave pulses. The transformation of the p-adic counterpart of the space-time sheet of the scalar wave pulse to a real one, a kind of switch-on process, could provide a generic realization of intention besides a direct generation of the p-adic counterpart of the negative energy topological light ray. The hierarchy of magnetic bodies could use this process as a generic manner to realize cascades of intentions proceeding from magnetic body down to the level of DNA.

Denoting by $f(\omega)$ the Fourier transform of single pulse in the interval $T(n,k)$, one can write the Fourier transform of the pulse sequence as

$$F(\omega_n) = \sum_k \delta_k exp(ik\tau_b\omega_n) f(\omega_n) \quad , \quad \omega_n = \frac{n2\pi}{T(n,k)} \quad ,$$

where τ_b is the duration of the bit and δ_k is equal to 1 or 0 depending on whether k^{th} bit corresponds to a pulse or not. The duration of the pulse can be anything in the range $(0, \tau_b)$. If $f_b = 1/\tau_b$ corresponds to a frequency of some oscillation a resonant coupling occurs. Magnetic transition frequencies and the frequencies corresponding to the increments of zero point kinetic energies are especially interesting as far as the transformation of the pulse representation to a conscious experience or controlled action is considered. For instance, pulses could correspond to magnetic pulses used in the transcranial magnetic stimulation and known to induce altered states of consciousness [J32].

2. Genetic and memetic codes as cognitive codes associated with spoken and written language

Genetic and memetic codes are the most obvious candidates for the codes associated with spoken and written language. Genetic code would correspond to $k = 2^7 - 1 = 127$ and one must distinguish between 6-bit(64 DNA triplets) and almost-7-bit representations. These codewords can be realized dynamically as temporal field patterns. For genetic code primes $p \simeq 2^k$, $k = 6 \times n$ define candidates for the duration of the genetic code word if all factors of k are assumed to define a possible number of bits of the code word. The time scales come as powers of 8 so that they cover the entire range of biologically relevant time scales and genetic code could appear as fractally scaled versions unlike memetic code. What is interesting is that the possible durations of code word range down to about 11 CP_2 times. Therefore one cannot exclude the possibility that the biological realization of the genetic code is only a particular example of its realizations and that genetic code makes possible communications even between living and so called non-living matter.

Representations of the genetic code

$k = 2 \times 126 = 2 \times 6 \times 21 = 252$ allows the representation of both 126-bit memetic codeword, 6-bit genetic codeword, and 7-bit code word. For pulse representation corresponding to $k = 252+6n$ the genetic codon the duration of the code word and bit are $\tau = 2^{-3n} \times 50$ ms and $\tau_b = 2^{-3n} \times 8.3$ ms respectively. The realization using nerve pulse patterns certainly possible for $n \geq 0$, $n = 1$ would $\tau_b = 1.04$ ms which seems to be somewhat too short. Frequency representation would be realized using the 6 first harmonics of the fundamental frequency $f_1 = 2^{3n} \times 20$ Hz. In the following only 6-bit representations are discussed.

1. Representations of 6-bit code in the range of audible frequencies

20 Hz corresponds to the lowest end of audible frequencies $(20 - 2 \times 10^4$ Hz). Audible range allows 3 representations of the genetic code corresponding to the fundamental frequencies f_1 equal to 20 Hz, 160 Hz and 1280 Hz. 1 kHz frequency is between the frequency ranges associated with the latter two representations. Above (below) 1 kHz the wavelengths of incoming sound waves are shorter (longer) than head size so that the mechanisms determining the direction of the sound source are different above and below this frequency. Speech might correspond naturally to pulse representations whereas music could correspond to frequency representations. Also nerve pulse-EEG dichotomy could correspond to talking-singing dichotomy (left brain speaks and right brain sings).

2. EEG and nerve pulse representations of 6-bit code

1. Cortical EEG frequency range favors the realization using $f_1 = 2.5$ Hz: all harmonics in the range 2.5-15 Hz are important EEG resonance frequencies. For 20 Hz representation 120 Hz would represent the highest harmonic and it is questionable whether cortical EEG contains it with a sufficient intensity. Cerebellar EEG however allows much higher frequencies than cortical EEG.

2. The cyclotron frequency of Si^{++} ion is 21.4 Hz so that it could define a frequency representation of the genetic code in Earth's magnetic field, at least if its value is subject to a homeostatic control.

3. Ca^{++} has cyclotron frequency of 15 Hz in Earth's magnetic field with value $B_E = .5$ Gauss. A pulse representation of the genetic code with $\tau_B \simeq 66.7$ ms ($f_b = 15$ Hz) would excite harmonics of Ca_{++} cyclotron frequency and thus couple the representation to the Bose-Einstein condensate of Ca_{++} ions. Nerve pulses could realize this representation. Blackman [J12] has found that the harmonics of $f_b = 15$ Hz frequency have effects in living matter, and Ca^{++} waves are known to play an exceptional role in biology [J31] (for TGD based model see [K51]. Hence the Bose-Einstein condensate of Ca^{++} ions might provide a fundamental pulse representation of the genetic code.

4. The presence of fractally scaled-up versions of the Earth's magnetic field the sheets of the many-sheeted DNA would allow also scaled versions of Ca^{++} representation with durations $\tau = 8^{-n} \times .05$ ms of the code word. Depending on whether magnetic flux quanta are tubes or sheets the p-adic primes of space-time sheets of magnetic flux tubes comes as $k = 169 - 3n$ or $k = 169 - 6n$. For sheets one would have $k = (169 = 13^2, 163, 157, 151)$: these primes define important p-adically scale up electronic Compton scales relevant to DNA in the range 10 nm-5 μm and three of these primes define Gaussian Mersennes. Sheet option is favored by the explanation of the findings of Peter Gariaev about radio emission induced by irradiation of DNA by laser light [I89]. All these representations except $k = 169$ are realizable also using audible frequencies, which suggests a direct connection between the sheets of the many-sheeted DNA and the representations of the genetic code at audible frequencies.

Representations of the memetic code

For the memetic code one must distinguish between almost-127-bit representations and 126-bit representations. In both cases there is a very limited number of representations, which suggests that the emergence of memetic code might relate to the emergence of explosive cultural evolution. The first representations corresponds to the time scales $T(126)$ and $T(127)$: the latter defines the Compton time of electron. Next representations corresponds to the time scale of about .05 seconds and.1 seconds respectively.

1. 126-bit representations

1. 126-bit memetic code word can be represented using the same representation as for the genetic code, namely $k = 2 \times 126 = 252$ with $\tau = .05$ ms and $\tau_b = .4$ ms and $f = 20$ Hz and $f_b = 2520$ Hz. Audible frequencies could realize both representations and music experience might involve both frequency and pulse representation of 126-bit memetic code corresponding to the left brain (rhythm) and right brain (melody) aspects of music.

2. 126-bit representation using nerve pulses as such is not possible. The analog of the intronic representation of the memetic code using sequences of 21 DNA triplets could be however possible. $k = 252$ allows 21-bit representation for which bit is replaced by 6-bit with duration $\tau_6 = 50/21 = 2.38$ ms, which corresponds to a typical duration of nerve pulse. Each of the 21 nerve pulses should generate a genetic codon of duration $\tau = 50/64 = .78$ ms presumably communicated to the neuronal nucleus and/or vice versa. 6-bit fine structure could be perhaps expressed at the microtubular level as has been originally proposed by Koruga [I80], [J17]. One would have $\tau_b/\tau_6 = 21/64$, the ratio of the number of amino-adics (stopping sign counted as effective amino-acid) to the number of DNA codewords. τ_b/τ_6

represents a reduction of information: this loss of information is not due to the degeneracy of the code but due to the fact that only one third of the total duration of the bit of 21-bit code is used to represent information.

One could imagine that the 6 bits represented as negative energy topological light rays activate the corresponding DNA triplet by coupling 3 switches on so that supra-current can flow through it. Sequence of 21 pulses would switch a unique memetic codon and sequences of these pulses in turn would switch on meme forming by definition a closed supra current circuit with return current flowing along conjugate strand. Switches could correspond to join along boundaries bonds connecting atomic space-time sheet to some larger space-time sheet, where the supra-current can flow. Each pair of bits would switch on one nucleotide of the triplet. This would occur in correct order if the three nucleotides are ordered by pulse length associated with bit (which can indeed vary) and 4 different bit pairs switch on A, T, C, and G. Bit could be represented by the polarization direction associated with the negative energy topological light ray.

The generation of nerve pulses using 64 bit sequence to code additional information at microtubular level could be based on frequency representation. Pairs of em MEs with opposite polarizations could represent a bit pair corresponding to a single nucleotide. These waves would induce microtubular excitation representing the DNA triplet.

2. 127-bit representations

For 127-bit representation the duration of the memetic codeword would be $T(2, M_{127}) = .1$ seconds. This time scale might be identified as the minimal duration of cortical mental images, and the so called features introduced by Walter Freeman [E2] could define a pulse representation of memetic code words of almost-127 bits. $\tau_b = .8$ ms is definitely too short a time scale to be realized by the neuronal dynamics alone. Frequency representation is realized utilizing 127 first harmonics of $f_1 = 10$ Hz, which defines the average frequency of alpha band and is fundamental hippocampal frequency. $f_b = 1270$ Hz could define the frequency responsible for synchronous neuronal firing known to be about 1 kHz. Note that the code word containing only f_1 would not generate any conscious experience (10 Hz is not audible frequency) so that the highest bit is not quite fully represented.

1. One can imagine at least two electromagnetic realizations (for the spectrum of magnetic transition frequencies see [K82]).
   i) Living matter contains both Co and Fe ions and the harmonics of Co_{++} and Fe_{++} cyclotron frequencies are 10 Hz for the nominal value $B_E = .5$ of the Earth's magnetic field. Thus pulse both pulse representations and frequency representations of memetic code coupling to these magnetic transitions are in principle possible.
   ii) For $B = 127/90 \times B_E$, $B_E = .5$ Gauss, both the third harmonic of proton cyclotron frequency and electron's spin-flip-cyclotron transition frequencies are 1270 Hz so that the bits of the memetic codon would couple to the Bose-Einstein condensate of the Cooper pairs of electrons and protons in the pulse representation.

2. Also classical Z^0 fields make possible realizations of the memetic code (for the spectrum of Z^0 magnetic transition frequencies see [K82]).

   (a) Z^0 cyclotron frequencies of nuclei are proportional to $(A - Z)/A$ and around 10 Hz if one assumes the earlier hypothesis that Earth's Z^0 magnetic field corresponds to the space-time sheet $k = 173$ [K79]. The value $(A - Z)/A = 1/2$ characterizing surprisingly many biologically important ions (C, N, O, S and Si [**?**]) is ideal in this respect. Thus it would seem that Z^0 cyclotron transitions might provide a rich repertoire of frequency representations of the memetic code. Note that neutron could define a cyclotron representation of the genetic code with 20 Hz fundamental frequency.

   (b) The temporal field patterns associated Z^0 topological light rays provide one possible pulse representation of the memetic code [K82].

   (c) Temporal sequences for the changes Z^0 magnetization directions for a block of cognitive antineutrinos at cell membrane space-time sheet provide a conscious pulse representation of the memetic codeword [K79]. Conscious experience would result, when the Z^0

magnetization directions flip back to the direction of external Z^0 magnetic field in spin flipping cyclotron transition. $M_{127} = 2^{127} - 1$ different conscious experiences results since nothing happens if all cognitive antineutrinos are in the direction of the external Z^0 magnetic field. Z^0 magnetization direction could be altered by the Z^0 magnetic pulse associated with the Z^0 ME inducing cell membrane oscillations of nerve pulse pattern.

8.5.3 Mapping Of The Memetic Code To Microtubular Code

The importance of microtubuli for long term memory is evident [J33, J17]. Microtubule decomposes into a sequence of cylinders containing 13×13 tubulins such that the helical twist is 2π along each of the 13 helical strands consisting of 13 tubulins. Therefore the code with $k = 13^2 = 169$ bits with bit realized as a tubulin conformation is a natural microtubular cognitive code [K66].

$k = 169$ defines the p-adic time scale associated with the Earth's magnetic field and next to the p-adic length scales $k = 151, 157, 163, 167$ associated with DNA so that microtubular level would naturally correspond to the level next to DNA in evolution, and have therefore some sort of self-reflective character. Microtubular representation of long term memories would certainly be consistent with this self-reflective character. This suggests that 169-bit microtubular code words represent the log file of neuron as a temporal list of activated 126-bit memetic code words with remaining bits representing parity bits making possible error correction at both microtubular and DNA level.

In the following some arguments for why microtubular code words should represent memetic code words are developed, and a mechanism for how to achieve this is proposed. Needless to say, this is only one possible scenario and it is easy to imagine variants of this scenario.

Microtubuli and long term memory

In spin glass phase tubulin conformations are spatially uncorrelated but temporally stable (the excellent articles of Dimitri Nanopoulos [J33, J17] provides a model for microtubule as spin glass). Therefore microtubuli in spin glass phase are ideal for the representation of memories coded to bits represented by tubulin conformations [K66], [J17]. The two tubulin conformations have different electric dipole moments and conscious bits would result as "spin-flips" when the microtubule is in a strong longitudinal electric field forcing tubulins to the same conformational state. Essentially ferro-electric polarization is in question. The fundamental quale would be the change of the tubulin conformation. The patterns for the changes of tubulin conformations would generate mental images, and could also give rise to conscious memories by sharing of mental images. They could also give rise to signals communicated classically to the geometric future where they could induce reverse transition generating copies of the microtubular code words.

Time mirror mechanism for the realization of intentions proceeding as a process initiated from the magnetic body allows to consider two possible options for the role of the microtubuli. The options are not of course mutually exclusive.

1. Microtubuli as log files and communication lines

For this option intentional action does not involve microtubuli and they would be specialized to represent memories and serve as communication lines. The intentional action from higher than microtubular level would affect intronic DNAs directly, and patterns of tubulin conformations would provide a log file listing the memetic codons activated during the history of the neuron. Since the hierarchy of the magnetic bodies must have been there for all the time, one an indeed argue that neuronal microtubules have emerged later and do not participate in the intentional actions at intermediate level. Intentional action and the memory about it would be decoupled from each other completely.

Microtubuli allow besides ferro-electric and spin glass phase also phase which is optimal for signal transfer. The proposed realization of memetic code words as sequences of 21 nerve pulses with each pulse accompanied by genetic codon would suggest that microtubuli also mediate propagation of memetic codon, which can represent the desire to activate corresponding memetic codon in the post-synaptic neuron. Here the error correcting code $K_2(13, 64, 5)$ originally proposed by Koruga [I80], [J17] could be involved.

2. Why microtubuli cannot serve as intentional agents?

One must also consider the option for which microtubuli would represent the last step before DNA level in the hierarchy of desires propagating downwards in the self hierarchy. One can however represent heavy criticism against this alternative.

1. One can wonder whether the microtubular memes are generated intentionally or in a random manner in a phase transition leading to spin glass phase with basically un-predictable meme sequence. In the latter case, intentional action would be reduced to a selection to activate or not to activate the existing memes.

2. In this case it would be possible to have long term memories about events that never occurred, which seems strange. Random generation of the memes would also be in conflict with the notion that there are at least 42 parity bits making possible error correction. Thus it would seem that microtubular codewords can be activated only from the DNA level. In the case that microtubuli act as signal pathways this would indeed be the case.

3. Not all memetic code word sequences representable at microtubular level need to have counterpart at DNA level. This would lead to a situations in which meme could not be expressed at all.

These arguments favor the view that microtubuli are passive historians making possible self-reflection by providing a log file about activated memetic codons and possibly serve also as communication lines allowing the propagation of memetic codons between neuronal nuclei as sequences of 21 nerve pulses accompanied by genetic codon each. Only this option will be discussed in the sequel.

3. How to generate and read microtubular code words?

The coding of the intronic memetic code word to a microtubular code word would involve switching-on mechanism in spin glass phase of the microtubule for which initial state consists of "0": s. The tubulins corresponding to bit "1" would make transition to the conformation representing bit "1". The activation of intronic meme should automatically generate the positive energy photons at frequency corresponding to the energy difference between two conformations of tubulin. Intronic memes should have kind of hardwired connection to a fixed ordered sequence of microtubular code words. Note that in TGD framework there is no need to static microtubular memory since memories can be communicated from geometric past. Therefore memory capacity would be unlimited in this sense.

The conscious reading of the microtubular code word using strong enough longitudinal electric field would generate positive energy photons, which could be communicated to the geometric future and generate declarative memory mental images. Also a direct sharing of mental images yielding episodal memories is possible.

Representation of the memetic code words as microtubular code words

The challenge is to understand how 126-bit genetic code word or (possibly 127-bit codeword) is mapped to 169-bit microtubular codeword. There are several hints how this mapping could be realized.

1. Number theoretical decomposition of the microtubular code word to memetic code word and 43 parity bits

It is possible to represent microtubular 169-bit codewords as $13 \times 13 = 169$ square lattice of bits.

1. One can write the number of microtubular bits as

$$169 = 126 + 43 = 3 \times 42 + 42 + 1 \ ,$$

and there is a temptation to assume that the first 126 bits correspond to the memetic codon and 42+1 bits represent parity bits making possible error detection. From the geometric

representation it is clear that the bit in the middle of the 13×13 square is an excellent candidate for "1" in $42 + 1$.

2. 126-bit memetic code word allows a natural identification of the parity bits. The $126 = 3 \times 42$ decomposition allows also 42-bit code word, whose bits are obtained by decomposing 126-bit code word to a sequence of 42 3-bits, and defining each bit B of 42-bit as some Boolean function $B = f(b_1, b_2, b_3)$, say as a product $B = b_1 b_2 b_3$ of the bits of the corresponding 3-bit by representing bits as 1 and -1: the result is -1 (bit "0")if the number of bits "0" is odd and 1 otherwise. The comparison of codewords with a reference codeword assumed to be the correct one would allow to locate errors leading to internal inconsistency of the code word. The comparison of 42-bit codeword with the original one would allow to locate single bit changes of the memetic code word with a resolution of 3-bits.

3. A possible interpretation of the 43^{th} bit results from the requirement that each memetic code word gives rise to a conscious experience. This is guaranteed if the bit in the middle of the square is always "1" so that in the phase transition it changes the direction always and conscious experience results even when all the remaining bits are "0": s: the interpretation in this case would be as a mental image representing "nothing happened". An alternative possibility is that this bit represents parity bit. For instance, the product of all memetic bits or of all 42 parity bits. This bit could also be "1" only if there are no erratic bits. This bit could also represent 127^{th} bit of the 127-bit memetic code word.

2. How intronic DNA could represent parity bits?

If microtubule represents passively the information communicated to it, intronic memes should be accompanied by 42-bit parity code words. The minimal portion of DNA helix containing an integer number of DNA triplets consists of 10 triplets and corresponds to a length of $L(151) = 10$ nm (cell membrane thickness). 20 triplets would correspond to 2 full 2π twists. This encourages to consider the possibility that memetic codons correspond to 3 2π twists (length of 30 nm) along DNA so that memetic code words are followed by by a sequence of 9 DNA triplets serving some control function. Since 10 nm corresponds to electron Compton scale $L_e(151)$, the idea that dark electrons with this Compton length are relevant.

These 9 DNA triplets represent 54 bits. 7 of these codons could represent the 42 parity bits of the memetic codon preceding it. The remaining two genetic codons (12 bits) should represent further control information. The factorization $Z_{126} = Z_2 \times Z_3^{a)} \times Z_3^{b)} \times Z_7$ allows to identify two coset groups $Z_{126}/Z_{21} = Z_6$ as $Z_6^{a)} = Z_2 \times Z_3^{a)}$ and $Z_6^{b)} = Z_2 \times Z_3^{b)}$ corresponding to the identifications $Z_{21}^{a)} = Z_3^{a)} \times Z_7$ and $Z_{21}^{b)} = Z_3^{b)} \times Z_7$. This would mean the possibility to define two non-equivalent 6-bit parity code words as products $B = b_1 \times ....b_{21}$ of 21 memetic bits corresponding to the two sub-groups Z_{21}. The two DNA triplets could represent these parity 6-bits. Needless to say, these prediction are very strong and immediately testable by studying the intronic DNA.

3. The helical structure of the microtubule and the representation of the memetic code word and of parity bits

The tubulins representing parity bits should differ physically from those representing memetic bits. Time mirror mechanism suggests that the energy difference between two tubulin conformations differs considerably from that for the memetic tubulins. A weaker symmetry breaking induced by the helical electric field should order the bits of helical genetic code words and also order the 7 genetic code words to a sequence of vertical pairs running from left to right. Genetic code words should correspond to connected regions, most naturally helical stripes. Also the memetic code word and parity bits should correspond to a connected regions. There should be a clear signature telling where the microtubular code word ends.

The breaking of the rotational and translational symmetries is necessary and the helical structure of microtubuli could induce it. Denote by a the vertical distance between tubulins and by $\Delta\phi = 2\pi/13$ the angular distance between two tubulins along horizontal circle.

1. Genetic codons would be arranged to the helical stripes rotating making full 2π around the vertical section section of the microtubule defined by 13×13 tubulins. The 10 helices span a helical region spanning the angle range $\Delta\phi = 10 \times 2\pi/13$. Each helix would represent

2 memetic codons whereas the 13^{th} tubulins at $z/a = 13$ would represent parity bit. This would give 20 genetic codons. The 21^{th} genetic codon would correspond to the 6 lowest tubulins of the 11^{th} helical stripe. Therefore the pairs of 2 sub-sequent genetic code words would correspond to helices beginning at

$$(\tfrac{z}{a} = 1, \phi = k \times \Delta\phi) \ , \quad (\tfrac{z}{a} = 7, \phi = k \times \Delta\phi + \pi) \ ,$$

$$\Delta\phi = \tfrac{2\pi}{13} \ , \qquad k \in \{1, 2, ..5\} \cup \{9, 10, ..13\} \ .$$

The 21^{th} code word would correspond to $z = na$, $n = 1, ..., 6$, $k = 11$. The region representing parity bits would be connected and consist of vertical part and the 13^{th} horizontal stripe. It turns out that this guess is probably quite not correct: it seems that the first pair of helices representing genetic codons starts at $(z/a = 2, k = 2)$ so that the horizontal line at $z/a = 13$ contains 12 tubulins (2 genetic code words).

2. Perhaps the simplest mechanism guaranteeing the desired symmetry breaking is based on a static helical electric field, which is non-rotational and thus representable as a gradient of a scalar potential V. Electric field could be constant in the memetic section of the microtubule since tubulins are charged and Coulombic interaction energy would grow linearly with the azimutal angle ϕ and longitudinal coordinate z along the helical strands. In this case the potential would be of form

$$V(z, \phi) = k_1 \times \frac{z}{a} + k_2 \times \frac{\phi}{2\pi}$$

in the region populated by the genetic code words.

The value of the potential should fall rapidly down at $z = 13 \times a$ defining the upper edge of the microtubular codon and the vertical stripes defining the parity bits. The strong gradient of the electric field in the parity bit region could give rise to a strong dipole interaction and change the energy difference between microtubular conformations dramatically both at $z/a = 13$ and inside the

   (a) lower helical stripe S_{low} having having height of 6 units and width of 2 units starting at $(z/a = 1, \phi = k \times \Delta\phi)$, $k = 12, 13$ and

   (b) upper helical stripe S_{up} having height of 6 units and width of 3 units and starting at $(z/a = 7, \phi = k \times \Delta\phi) + \pi)$, $k = 11, 12, 13$.

This behavior of electric field dictated by its non-rotational character would differentiate between memetic and parity bits.

3. Genetic codons are ordered to a sequence of pairs of codons if the value of the potential increases with constant steps along the helical stripe, and also in the transition from the top of k^{th} helical stripe to the bottom of $(k+1)^{th}$ helical stripe. This gives

$$k_1 = -\frac{k_2}{13} \ ,$$

which fixes the potential apart from overall scaling:

$$V(z, \phi) = V_0 \times (\tfrac{z}{a} - 13 \times \tfrac{\phi}{2\pi}) \ ,$$

giving

$$V(z = n \times a, \ \ \phi = s \times \tfrac{2\pi}{13}) = V_0 \times (n - 13 \times s) \ .$$

The length of a single tubulin in the vertical direction is $a \simeq 8$ nm and the outer radius of microtubule is $R \simeq 12.5$ nm [J33]. This gives $\Delta z/R\Delta\phi \simeq 1.32$ whereas $\Delta V_z/\Delta V_\phi = -1$ rather than $-1/1.32$ required by the orthogonality with respect to the helical strands. Thus the electric field can be regarded as a superposition of a field orthogonal to helical strands with a weaker field parallel to the z-axis.

4. The requirement that the 5+5+1 (5+5) microtubular codons are represented at the lower (upper) half of codon can be satisfied if the the value of the potential becomes in some sense too large at the point $(z/a = 7, \phi/2\pi = 11/13)$ and that this forces V to rapidly raise up from the minimum value

$$V_{min} = -137V_0 \ .$$

The maximum of the potential at $(n = 1, s = 1)$ given by

$$V_{max} = -12V_0 \ .$$

$(n = 1, s = 1)$ bit is non-memetic bit and shifted by one unit upwards from the horizontal $n = 13$ row of 13 bits: this distinguishes it as a natural candidate for the 43^{th} bit. With this identification the first helical stripe containing two genetic codons would start at $(n = 2, s = 2)$ and $n = 13$ horizontal line would contain only 12 points corresponding to two genetic codons. Vertical stripes of parity bits would contain 5 genetic codons represented as helical stripes. Thus all genetic codons would correspond to helical or horizontal stripes. Horizontal and helical genetic codons should differ somehow but the origin of difference remains unclear.

Symmetries of the genetic code and the error detection

The ratio of the number of the number of parity bits to memetic bits is $R = 42/126 = 1/3$ and almost equals to the ratio 21/64 of the number of genetic code words to the number amino-acids. If parity bits represent directly the "memetic amino-acids" the action of all memetic code words with given 42 parity bits is identical and the comparison of parity bits would be enough to check that everything is in good shape at the level of the memetic expression. Obviously, this option is trivial.

If the memetic code is directly induced by the genetic code, the ratio R would be $R = log_2(21)/6 \simeq .73$. For both options the number of the "memetic amino-acids" would be considerably smaller than $(2^{126} - 1)/63$ suggested by the direct generalization from the case of the genetic code, and corresponding to $R \simeq 20/21$.

If the memetic code is induced by the genetic code which is same for both chemical and field pattern expressions, intronic memetic codons possess the A-G symmetry and almost exact T-C symmetry of the genetic code in the sense that memetic code words related by these symmetries would activate the same genes. This would allow to improve further the error detection.

1. A-G and almost T-C symmetries imply that the last 2 bits of 6-bit defining genetic code word in good approximation reduce to single bit, say the last bit. Therefore the second parity bits could be taken to be the product b_4b_5. This improves considerably the effectiveness of error detection at the level of expression.

2. Also the first bit of the genetic code word is less significant since the genetic code table contains many 4-sub columns (codons of form XYZ, with Y fixed) for which all 4 amino-acids are same and quite a many 2-sub-columns (codons of form XYZ, X= A, G or X= T, C) are identical. Therefore a relatively safe choice is to take the first parity bit for the genetic codon to be the product b_2b_3. This choice would localize with a reasonable reliability the errors with 2-bit accuracy at the level of expression.

Could error correction mechanism be used to detect mutations of memes?

The first question to be answered concerns the purpose of the error correction process. Is error correction used

1. to remove the internal inconsistencies of the memetic code words at intronic level due to mutations or,

2. to stabilize long term memories represented at microtubular level?

Only the first option would be needed if the refreshment of the memetic code words by activated intronic DNA occurs all the subjective time in the geometric past. Both types of error correction could rely on the following mechanism.

The comparison of the microtubular code word with that of the geometric past by time mirror mechanism, assumed to yield resonant interaction if the compared code words are identical, could reveal the emergence of those mutations at DNA level which alter some parity bits and memetic bits in such a way that the parity bit pattern ceases to be consistent with the memetic bit pattern. There would be simply no internally consistent microtubular code words in the geometric past identical with this pattern. Large number of temporal copies of the codeword in geometric past would make the mechanism reliable.

The internally inconsistent change of the microtubular codeword and even a change in general could be detected by this mechanism. In absence of resonance a process trying to fix up the meme at DNA level by trial and error could be initiated and could yield an internally consistent or even original meme. Note that this comparison mechanism would be conscious and even the correction mechanism might be conscious intentional process.

To sum up, the model for the mapping of memetic code to microtubular code is dictated by the general ideas about realization of intentions and p-adic cognitive codes. When combined with general number theoretical arguments and physical considerations the model becomes highly unique. The prediction for the intronic representation of the memetic codon is readily testable, and also the prediction for the microtubular electric field is in principle testable.

8.5.4 Genes, Memes, And Language

The idea about intronic memes as computer programs running in the hardware coded by genes together with quantitative facts lead to a view about how memes and genes could relate to language. It must be emphasized that the idea about correspondence between genes and language is not new. The article [I88] gives a nice summary about various findings supporting the view that language and DNA are closely related.

Zipf's law

One of the basic resemblances between genes and language is Zipf's law relating the rank r of the event with its frequency f of occurrence [J23]. The rank of a given event is defined by ordering the events in sequence using as a criterion the frequency of occurrence: the event occurring most often has rank 1, etc.. Zipf's law states $f = C/r^a$, where a is a constant near one, and C is a constant depending on the size of the sample. In linguistics the event could correspond to the occurrence of a given word or character, and in genetics to the occurrence of a given DNA triplet.

Zipf's law holds also for many systems regarded as non-living, such as masses of stars in a constellation of stars. Interestingly, the sum of the frequencies for an infinite number of events is proportional to Riemann Zeta function $\zeta(a) = \sum_n 1/n^a$ at point $a \simeq 1$, which can be regarded as a product of thermal partition functions associated with primes regarded as bosons: $\zeta(a) = \prod_p 1/(1-p^a)$, $log(p)$ plays here the role of energy and a to the role of inverse temperature. Interestingly, the line $a = 1$ defines a critical line such that $\zeta(a)$ converges for $Re(a) > 1$. $a = 1$ corresponds to the temperature at which Bose-Einstein condensation occurs and the system becomes macroscopic quantum system. Thus Zipf's law might relate to p-adicity and macro-temporal quantum coherence in some deep manner.

There is also evidence in favor of a typological relationship between the words of human speech and DNA "words" (see the references in [I88]). The word formation appears to obey laws similar to those of formal genetics so that one can speak of dominant and recessive features, mutations, etc.. In [I88] graphical representations character sequences defined by written texts and nucleotide (A, T, C, G) sequences are studied (amino-acid sequences of long proteins would be more appropriate for comparison with character sequences). The fractal dimensions of the resulting planar fractals are in the range $0 < D < 1$. A random sequence of characters corresponds to $D = 0$ and repetition of single character to $D = 1$, whereas written texts correspond to $D = .7 - .8$.

Could the phonemes of language be expressions of DNA triplets?

The previous construction of representations of genetic and memetic codes, in particular the facts that the frequency $f \sim 10$ Hz represents the fundamental frequency associated with speech organs and that 20 Hz frequency represents the lower limit for audible frequencies and the rate of mRNA-amino-acid translation, suggest that memetic code might be involved with speech and speed recognition. Since the duration of a phoneme in speech is $\sim .05 - .1$ seconds, one must seriously consider the possibility that phonemes might somehow relate to genetic or memetic codewords.

The number of phonemes of native origin in Finnish language the same as the number of characters and equals to 21, the number of amino-acids plus stopping codon counted as an effective amino-acid. In English language the number of phonemes it is not so easy to estimate the number of phonemes since written language differs so much from spoken but the number is not too far from 21. In Russian the number of different characters is 32, half of the number of DNA codons. Certainly one cannot expect precise correspondence between the numbers of phonemes/letters and amino-acids and it might well be that DNA→phoneme coding differs from the DNA→amino-acid coding.

These findings together with the observation force to consider the possibility that phonemes might play a role similar to that of amino-acids, and be interpreted as resulting in the translation of DNA triplets to field patterns to neural activity to the motor activity of speech organs. Words in turn would represent analogs of protein sequences coded by sequences of DNA triplets. The fact that memetic code represents statements about statements would suggest that memes represented by introns correspond to higher level structures of language, kind of main computer program producing meaningful expressions of language while running. Words represented by genes could be the hardware of language or lower level language and DNA triplets would represent the basic material of the hardware expressed as phonemes. This would of course require expression of genes and memes in terms of field patterns inducing the generation of nerve pulse patterns.

Consonants carry more information than vowels (early form or written language used symbols only for consonants). This picture is consistent with the fact that the property of being consonant is determined by the very brief time interval in the beginning of the pulse sequence defining the phoneme so that the occurrence of high frequencies make it consonant. There are 8 (7) vowels in Finnish (English) language, which suggests that the first 3 bits of the generic codeword in the frequency representation and representing lowest frequencies are responsible for the basic vowels and the remaining 3 bits corresponding to the higher frequencies add to the beginning of the phoneme something making it consonant.

The frequencies for the occurrence of various phonemes should be the same as for the occurrence of the DNA triplets coding them. The simplest working hypothesis that the DNA-phoneme code is same as DNA-amino-acid code does not work in case of say Russian language (32 characters) but deserves a testing in the case of Finnish language. Of course, one could consider the possibility of context dependent coding of phonemes: also ordinary genetic code can be context dependent in some situations (the same codon codes for stopping sign or amino-acid depending on context). The prediction would be that the frequencies for the occurrence of phonemes would equal to those of amino-acids.

It is not possible to assign a definite duration to the intronic representation of the memetic codeword. Speech is indeed extremely flexible: the rate of speech can vary, vowels can be represented multiply, etc.. This variation would be made possible by flexibility at the DNA level or at level higher than this (magnetic body would control introns). If speech represents genetic code, 50 ms would however be a good guess for the minimal duration of phoneme and 20 Hz for the lower end of consciously experienced frequencies (as it indeed is). Rather remarkably, the rate for the translation of mRNA triplets to amino-acids is 20 nucleotides per second so that one codon corresponds to the duration of the genetic codon in $k = 252$ representation of the genetic code.

On the other hand, the memetic code words generated while listening speech or reading text could correspond to the mental images representing the meaning of a word, and could quite well have a duration of.1 seconds whereas the minimal duration of phoneme would be about 50 milliseconds. If time mirror mechanism is involved time is not problem: the understanding of speech would occur at the level of DNA in the geometric past. Same applies also to the production of speech: the desire to produce an expression of language would generate DNA activity in the geometric past.

The overall conclusion is that memes and genes of DNA would define language independent universal grammar introduced by [J34] [J34]. Languages would differ from each other only in the different association of phonemes to the DNA triplets. Also languages based on electromagnetic realization and not directly conscious to us are possible and even probable.

How memes could control genes in the production of language?

Language is not expected to be the only function controlled by memes. Memes could be responsible for a high level control of genes also in their ordinary activities. Memes would represent a higher level control structure utilizing the existing program like structures defined by genes activating genes. In case of language the fundamental expression would be in terms of field patterns inducing nerve pulse patterns inducing in turn speech motor activities.

Computer metaphor suggests that memetic programs correspond to sequences of memetic codewords with each memetic codeword defining a main program as a sequence of sub-program calls. Production of speech would mean activating these programs from magnetic body by time mirror mechanism. Genetic program calls would be realized as addresses pointing to genes defining the subprograms: 2^{126} different addresses is much more than needed to point to any desired gene. Also genes could use this addressing to point to other genes. The pointed gene could generate field pattern giving rise to a word or sequence of words or it could point to another gene. In this manner meme could generate entire sequence of words by inducing a sequence of subprogram calls (computer language LISP suggests a possible model for what occurs). Genes have a hierarchical structure, and one expects that higher levels of this hierarchy could fix the parameters determining the rate of speech, durations of phonemes, accents, emotional content, etc....

Pointing could be achieved by electromagnetic field patterns utilizing time mirror mechanism so that address would be expressed by negative energy topological light rays (phase conjugate laser waves). Pointing could be based on avoidance of starvation. Negative energy photons at the frequency serving as the name of the pointed system would induce the dropping of charged particles to a larger space-time sheet.

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.

The pointed system would lose energy and would generate negative energy topological light rays at characteristic frequencies to compensate the lost energy. If the frequency is higher, the pointed system would point to a lower level in the hierarchy of sub-programs. One cannot of course exclude the possibility that pointed gene points back to the pointing gene or meme. This could give rise to recursive self-referential program structures. At the lowest level of hierarchy there would be gene which act as a population inverted many-sheeted laser generating a cascade of positive energy photons at various frequencies and in this manner yielding the desired response.

8.5.5 Does Memetic Code Make Possible Communications Between Different Species?

The observations of Cleve Backster [J10] give scientific support for the view that plants react to human emotions. The TGD based interpretation would be as sharing as mental images. One can however ask whether sharing of mental images might make possible the development of more evolved communications involving signalling by codes. For instance, people in hypnosis report that they can share the experiences of plants and shamans claim that they can experience what it is to be an animal and communicate with plants. According to what the shamans of the South America tell, their refined medical knowledge is told to them by plants [J28]. In principle common intronic memes could make possible this kind of communications even between different species: these communications would not of course be conscious to us under normal circumstances.

Interspecies communications by sharing of mental images

Sharing of mental images does not require neither target nor receiver to be able to communicate symbolically. Therefore the target and receiver could be any living system: animal, plant, even bacterium. In TGD Universe one cannot exclude even "non-living" systems as targets and even sharers of mental images. The remote viewing of non-living targets is indeed possible and in this case either mental images of target or some system perceiving target are shared. Since emotions represent holistic summaries about contents of consciousness, they are good candidates for universal mental images and the sharing of emotions could occur even between different species.

Support for the extreme generality of the sharing of the mental images as a basic mechanism of remote viewing comes the fascinating experimental discoveries made by Cleve Backster [J5, J10]. These findings have led Backster to introduce the notion of primary perception, which seems to have a natural identification as sharing of mental images.

1. Plants, eggs, and even bacteria are able to have primary perceptions. Backster tells in the interview that even yoghurt got wild when he took a chicken out of refrigerator and began pulling off strips of meat. Plants respond electrically to strong negative emotions and to the violence or death suffered by other living organisms. That primary perception correlates with the strength of emotions conforms with the view that entropy gradients with respect to subjective time, which are indeed identifiable as emotions, measure the strength of perception.

2. Distance does not seem to matter much. Sperm separated by a large distance from its donor reacted when the donor inhaled amyl nitrate. White cells were found to remotely react to the emotions of their donors. Same was found to apply to plants and their owners.

3. Plants and even bacteria seem to have a defence mechanism resembling shock. If bacteria share the mental images of suffering organisms by receiving negative energy MEs sent by them, the shock could be interpreted as resulting from the depletion of positive energy resources (all excited states of population inverted many-sheeted lasers decay to the ground state) or be a mechanism preventing this depletion.

An interesting question is whether humans have lost this ability or is this reaction usually unconscious at our level of self hierarchy and whether human skin could exhibit galvanic skin response to say death of other life-forms.

Interspecies classical communications using common memes and genes

The assumption that even classical communications between different species are possible is much stronger hypothesis than the assumption that mere sharing of mental images occurs. The general model for interspecies communications using symbolic representations for the communicated information rather than mere sharing of mental images relies on the pan-psychic view about life and consciousness ("Everything is consciousness and consciousness can be only lost"). Also the hypothesis that speech and written language are only one particular realization of language involving at fundamental level memes controlling genes expressing themselves in one of the many possible ways, supports this view.

1. General model

1. If the intronic portion of the DNA corresponds to memone defining basic linguistic repertoire expressed using genes defining the vocabulary. Even plants could possess language possibly realized using MEs ("topological light rays"). Introns could control genes in terms of electromagnetic MEs and genes could could express themselves by MEs. Genes would define the words of the language. One could say that interspecies communications reduce actually to intercellular communications between cells of different species.

2. Successful communication requires that the languages of communicators have common portion in their vocabularies. Cells possessing common expressed memes defining basic expressions and genes defining the vocabulary could communicate with each other. Meme level

communications would be possible between any two eukariotes (organisms having cell nucleus): bacteria, plants, fungi, animals. Also communications between plants and humans would be possible.

3. Communications could occur by sharing of DNA level mental images induced by activated memes: negative energy MEs would make possible the needed quantum entanglement. Communications could occur also classically. The simplest form of classical communication would involve the coding of the meme to the field pattern of em or Z^0 ME to a name of meme using memetic code in turn activating the same meme in the receiving organism. Memes could express themselves by controlling genes in turn generating various types of expressions for the meme This could in principle allow even translation of memes to speech in altered states of consciousness in which back projection to ears would transform the internal speech to sounds.

4. The general model for sensory representations and motor actions based on time mirror mechanism involves both quantum and classical communications. There is a great temptation to assume that the same model applies also in the case of inter-species communications. Both the psychokinetic aspect corresponding to the remote motor action aspect, and the remote sensing aspect corresponding to the remote sensory perception would be present and would be essentially geometric time reversals of each other. Psychokinetic aspect of course represents more than mere communications.

5. Unless the code is universal so that the classical signal induces directly a standard mental image, most plausibly emotion, irrespective of species, a code assigning symbols to mental images must be established by sharing of mental images. There are good justifications to argue that the establishment of a code requires sufficiently intelligent communicators. On the other hand, even if the signals from say plant do not have any "meaning" for a human receiver, they could generate effects analogous to synesthesia.

6. Organisms living in symbiosis (say some insects and flowers) could have common memes and genes allowing them to communicate. Common memes and genes would be the analogs of common genes causing the coloring of the flower and insect to be similar. This kind of communication could also explain the refined medicine of South American shamans. Shamans tell that plants have taught this medicine to them. In the book "The cosmic Serpent" [J28], Jeremy Narby proposes that shamans communicate directly with the DNA of the plant and that bio-photons might be essential for these communications.

2. Are "skin senses" in preferred role in inter-species communications

The general model of sensory organs [K42] provides further pieces to the model. The basic hypothesis is that sensory organs are the seats of primary qualia and that the experiencing self corresponds to the magnetic body of size much larger than the material body. The feedback via brain to the sensory organs is assumed to make possible the active processing of the sensory input to sensory percept.

The model introduced also a division of sense to "brain" and "skin" senses motivated by the following observation. During the development of vertebrate embryo three basic types of cells are formed: ectoderm giving rise to skin and central nervous system, endoterm giving rise to many internal organs, and mesoderm giving rise to muscles, skeleton, connective tissue, ... What is remarkable is that the ectoderm giving rise to brain, spinal cord, eye, .. suffers an inversion during the formation of the neural tube. The wall of the neural tube is inverted so that inside becomes outside and vice versa. This explains the strange finding that the eyes of vertebrates are inversion of the eyes of invertebrates and apparently look very awkward from engineering view point.

This leads to the distinction between "brain senses" and "skin senses".

1. For "brain senses" (vision, olfaction) the back projection by the telepathic sharing of mental images from brain to sensory organs allows to build sensory percept as a caricature.

2. For "skin senses" (with hearing included) the entanglement of the sensory organ with brain is replaced with the entanglement with external world, and can thus give rise to remote sensing

based on the sharing of mental images using time mirror mechanism. This remote viewing need not be conscious-to-us except in special situations, say during hypnosis.

If this distinction is sensible, skin senses would be in a special role as far interspecies communications are considered.

A model for insect-plant communications

Callahan has made very important discoveries related to the olfaction of insects and insect-plant interaction. Callahan's work [I125, I67] demonstrates that the insect olfaction is based on infrared light generated by the odorant molecules interacting with the antennae of the insects. This might be true for our olfaction too. Callahan has also shown plants communicate with insects by generating infrared light [I67]. This finding conforms with the findings of Albrecht-Buehler [I105] showing that all cells contain microtubular structures acting as receiving antennae for infrared light. Furthermore, plants suffering from de-nutrition are found more easily by insects than healthy plants.

These findings encourage to consider the following mechanism for insect-plant communications. This mechanism could apply also to the plant-human interactions.

1. Insects generate infrared MEs propagating like massless particles inside low frequency negative energy MEs acting as bridges quantum entangling the plant and the insect. Both classical communications by positive energy IR MEs and quantum communications by negative energy IR MEs are in principle possible.

2. In the case that plant suffers from de-nutrition, it can gain metabolic energy by sending negative energy MEs received by insect. This gives for plant metabolic energy and at the same time generates the quantum entanglement bridge making it possible for the insect to find the plant. The same mechanism explains also the episodal memory feats of synesthetes: due to the over-activity of subcortical parts of brain the neurons of the left cortex suffer starvation and generate negative energy MEs providing them metabolic energy and simultaneously entangling them with the geometric past so that episodal memories result. Also the life review of NDE experiences could be a by-product of the neuronal starvation.

Are human-plant communications possible?

Concerning the ideas about human plant-communications, I am grateful for Peter Hageman [I1] for inspiring discussions. Hageman claims to be able to express "plant language" by "dancing" in meditative state, and has made detailed maps of motor expressions of plant mental images and proposed a detailed taxonomy about plant language, and also developed refined ideas such as the notion of dialect. It is easy to debunk Hageman's views since the interpretations necessarily involve a lot of subjective elements. One could imagine a scientific testing of Hageman's claims by checking whether the vocabulary defined by the bodily expressions is invariant of a given plant. Similar testing is used in the case of motor synesthesia.

The common portions of the memone and genome of plant and human would in principle make possible this communication. Thus the memes and genes, which plant can communicate to humans are those which are expressed also by some cells of the human body. Since plants do not have a central nervous system, it seems that the communicable memes and genes should correspond to rather primitive expressions common to us and animals. Obviously, the memes and genes responsible for the body language is a good first guess in this respect. Note however that genes could define lower level language and could also be communicated in this manner.

This body language representation brings in mind motor synesthesia in which sensory input from some sensory modality is expressed as motor activity. The memes and genes expressible by body language could of course be expressed also by using ordinary language. The universality of the memetic and genetic codes is indeed consistent even with the transformation of communications to linguistic expressions.

8.5.6 Intronic Portions Of Genome Code For RNA: For What Purpose?

The last issue of [I71] contains an article about the discovery that only roughly one half of DNA expresses itself as amino-acid sequences. A detailed summary of the results has been published

in Nature [I26]. The Encyclopedia of DNA Elements (ENCODE) project has quantified RNA transcription patterns and found that while the "standard" RNA copy of a gene gets translated into a protein as expected, for each copy of a gene cells also make RNA copies of many other sections of DNA. In particular, intron portions ("junk DNA", the portion of which increases as one climbs up in evolutionary hierarchy) are transcribed to RNA in large amounts. What is also interesting that the RNA fragments correspond to pieces from several genes which raises the question whether there is some fundamental unit smaller than gene.

None of the extra RNA fragments gets translated into proteins, so the race is on to discover just what their function is. TGD proposal is that the RNA gets braided and performs a lot of topological quantum computation [K4]. Topologically quantum computing RNA fits nicely with replicating number theoretic braids associated with light-like orbits of partonic 2-surfaces and with their spatial "printed text" representations as linked and knotted partonic 2-surfaces giving braids as a special case. An interesting question is how printing and reading could take place. Is it something comparable to what occurs when we read consciously? Is the biological portion of our conscious life identifiable with this reading process accompanied by copying by cell replication and as secondary printing using amino-acid sequences?

This picture conforms with TGD view about pre-biotic evolution. Plasmoids [I118], which are known to share many basic characteristics assigned with life, came first: high temperatures are not a problem in TGD Universe since given frequency corresponds to energy above thermal energy for large enough value of $\hbar$ [K38]. Plasmoids were followed by RNA, and DNA and amino-acid sequences emerged only after the fusion of 1- and 2-letter codes fusing to the recent 3-letter code. The cross like structure of tRNA molecules carries clear signatures supporting this vision. RNA would be still responsible for roughly half of intracellular life and perhaps for the core of "intelligent life".

I have also proposed that this expression uses memetic code which would correspond to Mersenne $M_{127} = 2^{127} - 1$ with 2^{126} codons whereas ordinary genetic code would correspond to $M_7 = 2^7 - 1$ with 2^6 codons. Memetic codons in DNA representations would consist of sequences of 21 ordinary codons. Also representations in terms of field patterns with duration of.1 seconds (secondary p-adic time scale associated with M_{127} defining a fundamental bio-rhythm) can be considered.

A hypothesis worth of killing would be that the DNA coding for RNA has memetic codons scattered around genome as basic units. It is interesting to see whether the structure of DNA could give any hints that memetic codon appears as a basic unit.

1. In a "relaxed" double-helical segment of DNA, the two strands twist [I60] around the helical axis once every 10.4 base pairs of sequence. 21 genetic codons correspond 63 base pairs whereas 6 full twists would correspond to 62.4 base pairs.

2. Nucleosomes [I43] are fundamental repeating units in eukaryotic chromatin [I10] possessing what is known as 10 nm beads-on-string structure. They repeat roughly every 200 base pairs: integer number of genetic codons would suggest 201 base pairs. 3 memetic codons makes 189 base pairs. Could this mean that only a fraction $p \sim 12/201$, which happens to be of same order of magnitude as the portion of introns in human genome, consists of ordinary codons? Inside nucleosomes the distance between neighboring contacts between histone and DNA is about 10 nm, the scale $L_e(151)$ associated with the Gaussian Mersenne $(1+i)^{151} - 1$ characterizing also cell membrane thickness and the size of nucleosomes. This length corresponds to 10 codons so that there would be two contacts per single memetic codon in a reasonable approximation. In the example of Wikipedia [I43] nucleosome corresponds to about 146=126+20 base pairs: 147 base pairs would make 2 memetic codons and 7 genetic codons. The remaining 54 base pairs between histone units + 3 ordinary codons from histone unit would make single memetic codon. That only single memetic codon is between histone units and part of the memetic codon overlaps with histone containing unit conforms with the finding that chromatin accessibility and histone modification patterns are highly predictive of both the presence and activity of transcription start sites. This would leave 4 genetic codons and 201 base pairs could decompose as memetic codon+2 genetic codons+memetic codon+2 genetic codons. The simplest possibility is however that memetic codons are between histone units and histone units consist of genetic codons. Note that

memetic codons could be transcribed without the straightening of histone unit occurring during the transcription leading to protein coding.

8.6 Corals And Men

The comparison of the human genome with that of invertebrates during great genome project yielded some surprises [I79, I109]. In particular, it was found that human genome possesses 223 genes which are lacking from the genome of the model invertebrates. Even more, a considerable fraction of these genes seems to be lacking even from the genome of other vertebrates and should have thus appeared relatively recently to the human genome. This led to the TGD inspired proposal that human genome has been subject to genetic engineering relatively lately with an even more crazy sounding proposal that intelligent intra-terrestrial life forms are responsible for this engineering (see [K32, K33]). Needless to say, this hypothesis is absolute non-sense unless one takes completely seriously the notion of many-sheeted space-time and related ideas (see **Fig.** `http://tgdtheory.fi/appfigures/manysheeted.jpg` or **Fig.** 9 in the appendix of this book).

Towards the end of year 2003 a new sensational result was published [I94]. The genome of certain coral, Cnidarian Acropora millepora, was compared with the genomes of fly (Drosophila melanogaster), nematode worm (Caenorhabditis elegans) and human genome. For simplicity, I shall refer to these animals as corals, flies, and worms in the sequel.

Before going to results, it deserves to mention that the phylum Cnidaria [I13] is a major group of invertebrates that includes the sea anemones, corals, jellyfishes, hydroids. Radial symmetry is characteristic for these animals whereas more advance animals have bilateral symmetry. All cnidarians are carnivors. The name cnidaria comes from "cnida", stinging capsules used to deliver toxin, to stick to a prey, or to entangle with an object. Cnidarians are believed to branch from the evolutionary tree much before flies, worms and vertebrates, and the expectation was that its genome should give information about the genome of the common precedessor of metazoans ("animals"). Obviously, coral genome should possess genome having much stronger resemblance to fly and worm genomes than that of vertebrates.

The astonishing result was that the genome of coral resembles human genome to a surprisingly high degree but much less the genomes of the fly D. melanogaster and nematode worm C. elegans. The conclusion of the authors is that the genes usually regarded as vertebrate inventions have been possessed by the believed-to-exist common precedessor of all animals, and that invertebrates have lost most of the genes common to human and coral during their evolution.

These strange conclusions are based on the existing wisdom about the evolution of animals and about the role of genome, and thus also challenge this wisdom.

1. The mutation rate of flies and nematode worms is high but it is not known whether genes can disappear. One can of course criticize the conclusion. Is the loss of genes, kind of "de-evolution", really a good survival strategy? Could it be that the gene loss hypothesis is dictated by some hidden assumptions? One can imagine several assumptions of this kind.

   (a) It makes sense to speak about continuously growing evolutionary tree from which corals branch before the emergence of the flat worms believed to be common precedessors of vertebrates, flies, worms, and other invertebrate phyla.

   (b) There are no of interventions from outside to the genetic evolution (genetic engineering by some more advanced life forms).

   (c) There is no horizontal gene transfer between corals and vertebrates (say fishes) living belonging to the ecosystems containing corals.

2. Corals possess relatively few tissue types. Coral is in fact the the most primitive animal possessing neurons. The neurons are organized into a homogenous neural net like structure. Therefore the presence of genes of vertebrates with highly developed nervous systems in the coral genome looks paradoxical. Could genes have some unknown functions besides those related to the coding of "hardware" ?

8.6.1 Why Corals And Vertebrates Should Have Common Genes?

The fact that corals and higher vertebrates have a lot of common genes, must have some sensible explanation. If flies and worms have never possessed genes common to vertebrates and corals, there must be something common to corals and vertebrates but not to higher vertebrates and flies, worms, perhaps all other invertebrates than corals.

1. Corals (polyps) are simple multi-cellulars consisting of two cell layers, epidermis and gastrodermis. The non-tissue layer between them is called the mesoglea. Corals are in a complex interaction with an ecosystem involving also vertebrates. Interestingly, corals are the only animals living in symbiosis with plants (dino-flagellates, which are simple mono-cellulars) providing them metabolic energy produced in photosynthesis. Social life requires communications and language of some kind, and this might explain why corals possess so complex genome.

2. Corals form large populations, coral reefs. One could regard coral reef as a super-organism, with corals taking the role of the cell in ordinary organisms. Some corals could even define super-neurons of the super-neural system of this super-organism. This could resolve the paradox caused by the simplicity of the nervous system of the coral itself viz. the complexity of the coral genome: complexity would reside in the connections and communications of the super-neural system.

3. Rather remarkably, both vertebrates and corals possess skeletons having calcium as a basic building brick. Coral skeleton consists of calcium carbonate $CaCO_3$ or limestone (calcium carbonate plus sediment). Usually the basic function of skeleton is thought to be that of a mere supporter but it might have also other functions as following arguments suggest.

   The function in question could be that of antenna.

1. Ca_{++} waves are known to play key role in the functioning of the nervous system [J31]. The finding, which led to the notion of magnetic body crucial for the functioning of living systems in TGD Universe, was that irradiation of living matter at the harmonics of Ca_{++} cyclotron frequency in Earth's magnetic field has effects in living matter [J12] and that these effects can be best understood if living cells are macroscopic quantum systems.

2. What makes Ca_{++} (and Mg_{++}) ions so special that they are bosons and can therefore form super-conducting Bose-Einstein condensates at the magnetic flux tubes of (say) Earth's magnetic field. The dropping of Ca_{++} ions from smaller space-time sheets to the magnetic flux tubes generates cyclotron radiation at the harmonics of the cyclotron frequency, and this mechanism is crucial for the generation of EEG.

   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 fact that EEG is associated with vertebrate neural systems and corals representing the simplest life forms having neurons, suggests that communications could be on Ca_{++} cyclotron radiation and be between neural systems of corals and vertebrates living around it. The calcium containing skeletons possessed by both vertebrates and corals could serve as antennae allowing to generate field patterns representing the communicated signals strong enough to make possible communications with say fishes.

   These observations can be combined with the earlier vision about the role of genome.

1. TGD based view for genetic code predicts that genes are not expressed only chemically but also in terms of field patterns representing one particular expression of the universal language

defined by genes and memes, the latter being represented by the intronic portions of the genome. The hypothesis is that common memes and genes make possible even inter-species communications. Thus DNA would not characterized so much species than communications in the ecosystem in which the species.

2. The proposed electromagnetic realization of the language defined by DNA and utilizing genetic code is as transitions at the harmonics of cyclotron frequency of Ca_{++} ions. The time $\tau_c = 1/f_c$ defined by cyclotron frequency $f_c = 15$ Hz of Ca_{++} ion in the magnetic field of $B_e = .5$ Gauss, defines the duration of the code word consisting of 6 bits. Bit "1" can be realized as a pulse of duration about $\tau_c/6$. Second realization if the codeword is as superpositions 6 lowest harmonics of cyclotron frequency generated when Ca_{++} ions drop to larger space-time sheets (bit "1" corresponds to harmonic with Fourier amplitude above critical intensity).

The combination of these ideas leads to the following vision about why corals and vertebrates possess common genes.

1. Linguistic communications based on electromagnetic field patterns are crucial for the functioning of the complex ecosystem formed by corals and various species belonging to it. In particular, fishes are vertebrates so that it would be advantageous for the coral to possess a considerable fraction of vertebrate genome responsible for the universal language.

2. The basic difference between humans and corals is due to the intronic portion of the genome, which dominates human genome and defines higher level linguistic structure based on menetic codewords with duration of.1 seconds and having 126 (or 127) bits. One could test whether fishes and other vertebrates living in the coral environment share identical genes with the coral.

8.6.2 Did Corals And Vertebrates Receive Their Common Genes Via Horizontal Transfer?

One can imagine several alternative models for how corals and vertebrates received their common genes. These "language genes" could have been "invented" by either corals or vertebrates and transferred horizontally from corals to vertebrates or vice versa. The most general view is that the system inventing the "language genes" was the entire system coral + vertebrates (possessing magnetic body), and the transfer of genes occurred in both directions.

Many-sheeted space-time allows to consider the possibility that the genes were transferred along magnetic flux tubes connecting the many-sheeted DNAs of corals and vertebrates involved (recall that many-sheeted DNA involves hierarchy of magnetic flux tubes with magnetic field strengths scaled by powers of two). The large sized magnetic body of the coral might have played essential role in this transfer. If one sees the magnetic body associated with corals and associated life-forms as a single conscious organism, this hypothesis looks natural.

Horizontal transfer of genes from vertebrates to corals?

Perhaps the simplest hypothesis is that the genes of vertebrates not possessed by invertebrates like flies and worms, appeared in the genome of corals, only after they were needed, that is during the co-existence with vertebrates as parts of same ecosystem.

The simplest possibility is a horizontal gene transfer from vertebrates to corals, so that vertebrate genes could be seen as genuine vertebrate inventions as usually believed. Since corals possess calcium backbone, it is indeed sensible to transfer "language genes" to corals. The transfer of "language genes" could have occurred also to other organisms but, by the absence of Ca containing skeleton, the transferred "language genes" would have been useless for them. The genes coding for the calcium containing skeleton of coral must have been present from the beginning, and for this option must be independent of "language genes".

Horizontal transfer of genes from corals to vertebrates?

The horizontal transfer of genes could have also occurred from corals to vertebrates so that vertebrate genes could be seen as coral inventions. This makes sense if the common genes were primarily involved with the communications between corals and vertebrates so that the co-evolution of vertebrates and corals was basically evolution of communications using genetic code. Also the vertebrate genes responsible for coding Ca_{++} based structures like bones should have counterparts in the genome of the coral. If corals possessed neurons from the beginning, the genes allowing to differentiate the cell to a neuron could have been transferred, not only to vertebrates but also to the invertebrates with nervous system, and corals could have functioned as a kind of organizing centers of evolution.

8.6.3 What Happened In Cambrain Explosion?

The most science fictive hypothesis is that the vertebrate genes were possessed by corals from the beginning. Ironically, this is the hypothesis forced also by the standard view about evolutionary tree. Since these genes had no function at the time when even flat forms preceding flies, worms, and vertebrates were still absent, the only reasonable conclusion seems to be that some advanced life forms intervened the terrestrial evolution somehow.

There are two basic options.

"Language" genes could have appeared to the genome of coral by some kind of genetic engineering. Since corals are the simplest organisms possessing neurons, also the genes responsible for the differentiation of cells to neurons could have emerged during this intervention.

2. Corals themselves could have been these extra- or intra-terrestrial life forms possessing these genes.

Corals would have served as kind of gene banks and "language" genes would have been transferred horizontally to the genomes of vertebrates during the evolution of the ecological coexistence with vertebrates such as fishes. "Neuronal genes" would have been transferred also to other phyla than future vertebrates.

Obviously, this intervention could have have induced profound changes, entirely new phyla could have emerged as a result of these genetic modifications by horizontal gene transfer. Although this scenario sounds un-necessarily science-fictive, it deserves a serious consideration since, as will be found, it could allow to resolve the puzzles related to the Cambrian explosion.

This option can be tested by looking whether corals possess genes possessed by higher vertebrates like humans but not by any of the vertebrates, which have possibly been members of same ecosystem with corals. One could also try to test the hypothesis that coral has possessed "language genes" already at Cambrian period. This could be the case, if "language genes" and genes coding for Ca^{++} body of coral belong to the same gene cluster.

Did Cambrian explosion involve the intervention of intra- or extraterrestrial life forms?

According to the fossil records, multicellular fauna emerged suddenly in the so called Cambrian explosion [I132]. Already Darwin realized that the absence of fossils from pre-Cambrian era posed serious challenges for the idea about gradual evolution in which evolutionary tree develops gradually new branches. The problems are following.

1. Why did the Cambrian explosion occur so late? This problem is discussed in the chapter [**?**].

2. Why no fossils of the pre-Cambrian precedessors of the Cambrian fauna have been found? The obvious explanation is that the faunas of pre-Cambrian era did not contain hard parts and thus yielded no fossils. During last decades two pre-Cambrian faunas have been however found. Edicaria are multi-cellulars with a pan-cake like shape whereas Tommotian fauna consists of simple cup and cap like multi-cellulars [I132]. Contrary to what one might expect, there is however no continuous evolution of these faunas to the Cambrian fauna and it seems that Cambrian explosion suddenly generated the precedessors of the recent day fauna.

3. The third problem which Darwin could not yet face emerged much later. The Burgess Shale fauna found 1909 by Charles Doolittle Wallcott challenged even the very notion of the evolutionary tree (for an excellent popular discussion of implications of Burgess Shale fauna see the book "Wonderful Life" of Stephen Jay Gould [I132]). It was found that several phyla of animal kingdom (kingdoms consist of phyla), which do not exist today, emerged in Cambrian explosion and then disappeared. The usual view about evolution is that it creates complexity from simplicity rather than vice versa. Obviously, just the opposite occurred in Cambrian explosion. Even more remarkably, not a single phylum has appeared to the fauna after the Cambrian explosion.

All these problems would have a nice resolution if Cambrian explosion were due to the intervention of intra- or extra-terrestrial life forms. Suppose that life evolved in intra-terrestrial conditions, in the safe womb of Mother Gaia, one might say. In this frame of mind Cambrian explosion could be seen as a moment when Mother Gaia gave birth to new phyla preceding the recent day fauna. After the moment of birth these children of Mother Gaia had to survive by their own in the harsh Cambrian environment and many of them did not. This would elegantly explain why Cambrian explosion was followed by a strong extinction of phyla.

The metaphor about mother Gaia giving birth to life forms could have at least two meanings.

1. The most concrete meaning is as the emergence of these life-forms from intra-terrestrial conditions to the surface of Earth: many-sheeted space-time might make this Jules Verne like travel possible. Corals might have been these intra-terrestrial life-forms realizing genetic code in terms of field patterns using calcium containing skeletons as antennae, and being the first animals possessing primitive nervous system and ability to realize genetic code electromagnetically in EEG frequency range. After this the horizontal transfer of intra-terrestrial genes would have stimulated the evolution of vertebrates from more primitive life forms and have generated various phyla.

   Although corals are simple life forms, coral populations are not, and they could be seen as super-organisms with cells being replaced by double cell layers, corals. If this interpretation is accepted, coral populations represent "alien" life forms at a higher level in the evolutionary hierarchy. This interpretation would make natural the identification of corals as organizing centers of evolution. The radial geometry of corals would nicely symbolize their role as evolutionary organization centers.

2. A less concrete realization of the metaphor would be as intra-terrestrial genetic engineering involving the insertion of packets of introns and genes (software plus necessary hardware) to the DNAs of already existing life forms. Of course, option

3. could be seen as are representing a special manner to perform this genetic engineering by utilizing a life form possessing the genes possessed also by the highest vertebrates and radiating them horizontally.

Variants about the genetic engineering theme

The idea about genetic engineering performed by intra- and/or extraterrestrials could have been realized in several ways.

1. The first vertebrates got their vertebrate genes from intra- or extraterrestrials, and these genes were horizontally transferred to corals living in symbiosis with them. This genetic intervention should have occurred after the Cambrian explosion if it turns out that the nearest precedessors of vertebrates do not possess the common genes.

2. The transfer of genes was from corals to vertebrates and corals received their vertebrate genes in Cambrian explosion from some highly advanced life form, or corals themselves were this advanced life form. During the gradually evolving co-existence with simpler life forms these genes were gradually horizontally transferred to the precedessors of recent day vertebrates.

3. Corals and the precedessors of the vertebrates living in symbiosis with them got their common vertebrate genes simultaneously from outside. Note however that they could have been inventions made by the entire ecosystem in question.

8.6.4 What Ontogeny Recapitulates Phylogeny Principle Means At The Level Of DNA?

The idea about corals as a gene bank could resolve some other mysteries related to the genome.

1. The revised view about the evolution of organisms possessing nervous systems would not rely so much on mutations but already existing and possibly conserved gene and meme banks inherited from corals. Only a fraction of these genes would be in use and evolutionary pressures would determine which portion of these memes/genes is activated. Mutations might only have a secondary and mostly harmful role in the evolution.

2. Introns are the basic candidate for the gene reservoir. This conforms with the idea that introns code for memes since it is plausible that the activation of memetic programs becomes possible only when genes coding for the needed hardware are activated.

The quite recent finding [J38] that the removal of massive portions of the conserved part of the genome has no apparent effect on the organism's functioning supports the idea about genetic repertoire. It is usually believed that conserved regions of genome have some function. Many of these conserved regions are in the "junk" portion of DNA and do not code for proteins. They could however still have some function and in some cases the conserved regions indeed seem to affect the expression of the nearby genes. To identify the function of the highly conserved intronic regions the team of Edward Rubin at the Lawrence Berkeley National Laboratory deleted two huge regions of intronic DNA from mice containing nearly 1000 highly conserved sequences shared by human and mice. One of the chunks was 1.6 million DNA bases long, the other one was over.8 million bases long. The unexpected result was that the genetically modified mice were virtually indistinguishable from normal mice in every characteristic they measured, including growth, metabolic functions, lifespan and overall development.

The result could be understood if the intronic portion of both mice and men derives from a very early period of evolution, perhaps the evolution leading to corals (where-ever it occurred). These conserved genes would have developed to their stable forms during the evolution leading to corals and represent a repertoire of functions waiting for their activation. One could understand the instantaneous popping up of highly developed biological functions, which is often used as a counter argument against the view that the evolution is made possible by random mutations. The interpretation also conforms with the idea that at least part of introns code for memes. In the case of mouse memone would not be yet of much use since speech organs and culture are lacking. The comparison of the introns of man and apes to see whether memes having some function related to language are active in humans but not in apes could serve as a test of this prediction.

Ontogeny recapitulates phylogeny principle would be realized as a gradual shift of the activated portion of the memone and genome during the development of the embryo. Also the memes and genes still waiting circumstances allowing for their expression would be present in the DNA. It might be possible to create artificially earlier evolutionary forms of a given organism and evolution might be studied in the laboratory. The partial transmutation of the morphologies of two different organisms to each other might be possible if the organisms possess common portions of the conserved genome.

If also the future phylogeny is coded to the recent DNA, both mice and men would possess enormous evolutionary potential (frog to prince effect!). Perhaps the explosive cultural evolution of civilization during last centuries has been accompanied by a corresponding shift in the activated portion of memone. This shift could also occur during the lifespan of individual and the idea about personal growth would have a genetic justification. The evolutionary potential might be some day be utilized by the artificial activation of memone and genome. Of course, the activation of higher memetic programs would be possible only if the genes coding for the needed hardware are also present and activated. Again the computer metaphor would work: I have used only a minor portion of the potential of my text processing program to write this piece of text.

Gene activation by electrostatic fields?

The basic question concerns the method of activation. The discovery of chemists Guido Ebner and Guido Schuerch [B10] , [J3] 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. These

findings are briefly described in the article of Hardmuth Mueller [B10] who proposes quite different explanation for the strange findings. 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 Novaris) applied for a patent "Method of enhanced fish breeding" [J3] 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 report [J3] that also 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 (it is not difficult to guess the reasons why!). 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).

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 the ontogeny could mean a gradual shift of the activated part of the memone 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 the exposure to an electrostatic field. This would suggest that in the case of primitive life forms like bacteria the electric field strength of Earth controls the state of bacterium whereas in higher life forms endogenous electric fields have taken the role of Earth's electric field.

Electric fields and healing

Wound healing is very much like morphogenesis and already Becker discovered that electric field induces a healing of wounds [J8]. More recent studies of the effects of electric fields on healing and on embryos are discussed [J13] and one can find useful quantitave information from this article. The typical strengths of the electric fields appearing in organisms are in the range.01-.1 kV/m: the upper bound of this field is the lower limit of Earth's recent electric field strength and considerably below the field yielding Ciba Ceigy effect. There are however also much stronger fields present: the voltage over epithelium (double cell layer) is in the range 30-50 mV and would make 6-10 kV if the thickness of epithelium were 5 μm. In the 1950s it was discovered that the direction of external electric field determines whether a flatworm which has been cut in two pieces develops head or tail. A natural voltage gradient exists between the severed worm's tail and the place where its head once was. A naturally occurring electric field of strength 40 V/m has been found to play a vital role in the wound healing in the cornea of rats: it is found that the cells divide in the plane orthogonal to the field and pushing new cells to the wound.

A further finding reported in [J13] was that a voltage of 2 mV over cell diameter (1 kV/m if cell radius is 2 μm and in the same range as the field applied in Ciba Geigy effect) alters the front back orientation of the neuroblast. The proposed interpretation of these findings is that electric field provides only directional information whereas the findings of Ebner suggest that much more profound meme/gene level effects might be involved. For instance, one can ask whether the

exposure to an appropriate external electric field could induce the return of a differentiated cell to the stem cell stage realized as a shift in the activated portions of memone and genome.

Generalized four-wave mechanism and the concrete mechanism of gene activation by static electric fields

Concerning the concrete mechanism behind the activation there are several constraints. The activation mechanism must be localized at the level of DNA. On the other hand, a given region of DNA must activate only in an electric field of a particular strength coding for its evolutionary age. The basic finding of Ebner about "wake-up" of ancient bacteria in a static electric field suggests that the activation must be a kind of "wake-up" process for an appropriate part of DNA. "Wake-up" corresponds to the generation of self-organization pattern getting its metabolic energy by sending negative energy photons absorbed by some system with corresponding excitation energy. This mechanism is indeed non-local since only the strength of the electric field matters. The transfer of an electron in an electric field through a distance not larger than the size of nucleus by absorbing negative energy photon is a good candidate here.

The generalized four-wave mechanism for remote metabolism requires the existence of generalized standing waves taking care of themselves by sending negative energy (phase conjugate) photons at the energy defined by the frequency of wave. The ideal situation corresponds to a dispersion relation for which the frequency of the oscillation does not depend on wave vector at all: plasma oscillations satisfy this conditions. In the chapter [K51] a model for the coherent electric dipole oscillations was constructed. In this case the frequency depends only on the angle between the wave vector and the direction of the electric field. Same applies to magnetostatic oscillations [D5] for which the Larmor frequency of electron gives the maximum value of frequency. The frequency is constant for effectively 2-dimensional oscillation patterns with wave vectors at the surface of a cone and periodically recurring oscillation patterns able to represent simple 2-dimensional self-sustaining mental images become possible.

Quantitative estimate support this model. In a field of.5-2 keV/m the electron gains a kinetic energy of $5-20$ μeV while travelling a distance of 10 nm corresponding to the thickness of cellular membrane. This corresponds to photons with microwave frequencies in the range .12-.48 GHz and wave lengths in the region.6-2.5 m so that the energy can be sucked from quite large spatial volume by inducing transfer of electron through this distance without a gain of kinetic energy. These frequencies corresponds to the nanosecond scale assigned with the coherent electric dipole oscillations whose importance was first realized by Fröhlich [I110]. In the above mentioned model of coherent dipole oscillations as analogs of magnetostatic oscillations these frequencies correspond the p-adic length scale $L(151) = 10$ nm associated with cell membrane thickness which is of central importance in the coiling hierarchy of DNA.

Also magnetostatic waves in a magnetic field associated with some level of the hierarchy of DNA space-time sheets could be in question. In this case the Larmor frequency of electron defines the maximal oscillation frequency. From the assignment of $L(169) \simeq 5$ μm to the Earth's magnetic field, the length scale associated with the needed field varying in the range $.05-.1$ Tesla is in the range.1-.2 μm.

8.6.5 Where Did Those 223 Genes Pop Up?

The reports of the Public Consortium about human genome in Nature, Feb 15, 2001 [I79] and of Celera Genomics in Science of Feb 16th, 2001, [I109] contained two big surprises.

Are we really so near to fruit flies?

The first astonishing discovery was that the amount of human genome differs relatively little from those of lower organisms: we have only about 30, 000 genes, little more than twice the number 13, 601 of genes for fruit fly. This paradoxical finding forces to think that our genome is not solely responsible for what we are and that the intronic portion of DNA (only about 1 per cent codes of human DNA codes or amino-acid sequences), is not "junk DNA", but contains important biological information and expresses it non-chemically.

In TGD Universe introns would express memes as the classical field patterns associated with MEs ("topological light rays") responsible for the basic expressions of language understood in an extremely general sense. This language includes body language and even cellular signalling, and could quite well make possible (not necessarily conscious) interspecies communications based on memes expressed by communicating species and forming a common vocabulary. All eukaryotes (cells with nuclei), even bacteria, would possess part of the vocabulary of this universal language. The memetic code word is predicted to consist of a sequence of 21 DNA triplets and carries 126 bits of information instead of 6 bits of genetic code. Of course, also genes are expressed in terms of MEs and define a lower level language.

In this framework the actual role of DNA can be understood using the computer analogy. Memes represent the program modules written using the programming language defined by the memetic code, and realized in terms of the field patterns associated with MEs. Genes represent the necessary hardware needed to realize these programs. System builds only the hardware needed, that is cell expresses only part of the genome. DNA engineering requires besides the addition of the new programs (memes, introns) also the insertion of the necessary hardware (new genes). Memes and corresponding genes should have very intimate relationship. In this conceptual framework the standard view is wrong since it identifies the build-up of a new hardware as the sole activity at the DNA level. This would be like identifying the addition of a net card to a computer as the fundamental activity related with computers.

The head-scratching discovery

The "head-scratching discovery" by the public consortium, as Science termed it, came when the genome was compared with the genomes of our precedessors. It was found that human genome contains 223 genes not possessed by invertebrates. Contrary to what one might expect, these 223 genes could make an enormous difference. The reason is that this number is more than two thirds of the number of the 300 genes differentiating between humans and chimpanzees so that these genes could be the main determinant of the dramatic difference between humans and chimpanzees in standard genetics.

Of course, in TGD framework the most important differences would probably relate to the intronic portion of the DNA responsible for language. Dramatic differences between our intronic DNA that of our invertebrate and perhaps even vertebrate precedessors, in sharp conflict with the idea of continuous evolution, should be discovered.

Are the enigmatic genes a horizontal gene transfer from bacteria?

Biologists can explain the presence of the enigmatic genes only by a "rather recent horizontal transfer from bacteria". Here "rather recent" refers to the evolutionary time scale.

This explanation can be challenged on various grounds.

1. The simplest working hypothesis is that the transfer from bacteria is a probabilistic process. The problem is however why the horizontal transfer did not occur to the genomes of other vertebrates and invertebrates and gradually through the whole evolution. One could argue that something characteristic to the vertebrate genome should have made this process possible. In TGD framework one could imagine that the intronic portion of the vertebrate genome could have contained something which made the transfer possible: a common part of memone with the bacteria involved and making possible language based communications ("language" understood in a generalized sense) at DNA level perhaps?

2. The enigmatic genes are involved with important physiological functions. In particular, they are responsible for important neurological enzymes which stem from mitochondria having its own genome. According to my non-professional interpretation this statement means that also mitochondrial genome contains these enigmatic genes. Thus both mitochondrial and nuclear genomes would have been altered by this horizontal transfer from bacteria. Simultaneous double horizontal transfer does not however look a probable event.

3. Only 113 of the 223 enigmatic genes are widespread in bacteria: it would be easier to believe in the horizontal transfer if all of them were widespread. These 113 widely occurring genes

are not encountered in invertebrates at all. As a matter fact, this finding suggests that the transfer occurred from the vertebrate genome to the bacterial one and only partially, rather than vice versa. The analysis of proteins expressed by the enigmatic genes demonstrated that out of 35 identified, only 10 had counterparts in other vertebrates. 25 of them were unique to humans. This suggests that a considerable part of the horizontal transfer has occurred relatively recently and together with associated introns might even distinguish us from chimpanzees.

Horizontal transfer as DNA engineering?

The objections against the horizontal transfer from bacteria force to consider seriously the possibility that the horizontal transfer represents an intentional DNA engineering, both memetic and genetic. The most important transfer should have been to the intronic part of the DNA. The addition of memes would be like adding a new program to a computer. The addition of genes would be like adding a new hardware (say net card or data cable) required by the program to run. The comparison of the intronic portions of DNA of humans and lower vertebrates might thus lead to futher "head-scratching" discoveries. The data are consistent with the assumption that genetic/memetic engineering activities have occurred in several steps during the evolution of the vertebrates although a considerable portion of the enigmatic genes and associated introns, perhaps even two thirds, have been "injected as a single dose".

The evolution of the hominides in Africa had a stagnation period of about 1.5 million years as demonstrated by the study of the ancient stone tools. Then, for about 50 thousand years ago, a sudden jump to creativity occurred. The first ornaments appeared meaning that hominides had become artists and started to express their position in the social hierarchy by clothing and ornaments. This signals about development of highly refined social structures. A general belief is that also language began to develop rapidly and made possible a cumulation of knowledge. It seems that modern human was born and started to migrate from Africa to North. Could it be that memetic engineering induced this crucial step in evolution? Could it be that Neanderthals had to leave because they were not subject to this memetic engineering? Also the emergence of the first civilizations for about 10 thousand years ago might have involved memetic engineering. The ancient Sumerian myths about Gods who came from Heaven and made us their images might be memetic fossils reflecting what occurred.

Who performed the (memetic and) genetic engineering?

One can imagine two identifications for the ancient genetic/memetic engineers.

1. The guess that the engineers were extra-terrestrials (ETs) is supported by ancient myths. The Sumerian and Akkadian texts found inscribed on clay tablets, in which the role of the Elohim in Genesis is performed by the Anunnaki, tell about "Those Who From Heaven to Earth Came". These myths would relate to the last step in the sequence of engineering activities.

2. The second guess is that genetic engineering is due to a highly advanced civilization of a remote geometric future, perhaps futuro-terrestrials, and applying highly advanced technology based on time mirror mechanism and possibly utilizing simpler life forms, perhaps plasmoids, as their couriers. Abduction experiences might relate to genetic manipulations using plasmoids to do the hard job. In this case encounters with aliens would be based on sharing of mental images.

3. The third guess is that genetic engineering is self engineering. The work of Yu. Chen Kangeng gives evidence that the transfer of the genetic information by electromagnetic means is possible [J2]. According to [I88], where the method is summarized, the successful transfer of the genetic information from a donor bio-system to an acceptor system was achieved via high-frequency electromagnetic fields feed repeatedly through the optically-active donor bio-system and then delivered over a long period of time to the receiving bio-system in its early developmental stages. The hybrids created through the irradiation of eggs and seeds with such "genetically loaded" fields are claimed to show very specific mixed characteristics that

were transferred to the next generation without need for further irradiation. This idea is discussed in [K106] on basis of a proposed realization of genetic code at the level of dark matter.

It would seem that the donor genome or parts of it are imprinted to the electromagnetic field pattern in the process and that this field pattern is able to modify the target genome.

Nothing precludes the possibility that genes/supergenes/hyper genes at some level of dark matter hierarchy can also code for genetic self engineering since these activities are after all very similar to other genetically coded bio-chemical activities. The computer analogy would be programs writing programs. The engineering genes would be activated by W MEs inducing plasma oscillation patterns. The claimed effects could be understood if the interaction with genetically imprinted electromagnetic field pattern activates genes inducing genetic self engineering yielding the genetic modifications consistent with the pattern represented by the em radiation.

Magnetic body would receive information about the desired outcome as electromagnetic field patterns emitted by other organisms, most naturally members of the same species. If these modifications are successful, the magnetic body is exposed to this information for long enough time to react and activate W MEs inducing the genetic program inducing the genetic program leading to the suggested genetic modification.

Hyper-genes integrating groups of organisms to larger wholes would be naturally involved with the mechanism. This mechanism would guarantee a rapid propagation of successful genetic modifications to the entire population and would be much more effective than the slowly occurring selection of random mutations. The possibly existing genes responsible for the genetic self engineering could be also introns and express themselves by activating nuclear RNA and process like reverse transcription.

Chapter 9

Many-Sheeted DNA

9.1 Introduction

The problems of how genes code information about the morphology of organism and how this information is expressed, belong to the great puzzles of developmental biology. A closely related mystery is the differentiation of cells. The notion of genetic program is far from precise and it is not clear how close the analogy with a computer program is. There are also several problems which challenge the basic dogmas of genetics.

1. Only 1 per cent of DNA of human genome actually codes polypeptides. Eukaryote genes contain intron sequences which are transcribed into hnRNA but snipped off when hnRNA is transformed mRNA in a process called slicing. The higher the evolutionary level of organism, the higher the fraction of introns is. Molecular Darwinists see introns as "junk DNA" but there is evidence that introns are far from junk. For instance, the splicing of the intron contribution from hnRNA to give mRNA can give several different outcomes depending on the stage of the development of the organism and introns are crucial for the effectiveness of the immune system [I76]. Hence one can wonder whether intron mRNA and exon mRNA could both form the real output of gene subprograms serving in some sense as input for other gene subprograms. This interpretation obviously conflicts with "gene-single protein" dogma in its basic form.

2. There are large amounts of highly repetitive DNA which is silent. One can wonder whether there is some fundamental mis-understanding involved. Could it be that this DNA is analogous to control DNA not transcribed to RNA and therefore not at all useless. There is also active repetitive DNA.

3. There is large amount of silent DNA in control sections between genes. Could it be that this silent DNA expresses itself in some non-chemical way? Chemical expression is very slow, translation rate being twenty amino-acids per second, and one can wonder whether life might have invented faster modes of gene expression and control of gene expression. Also the question whether there is a relation to the typical frequency scales of brain consciousness of order 10 Hz, which can be related to the magnetic and Z^0 magnetic transition frequencies, can be raised.

4. Plant genome is often by a factor of hundred longer than human genome. One could argue that the complexity of organism is measured by the length of the shortest program coding the organism. It is however not at all obvious how the genome of plants could be more redundant than human genome since repetitive sequences common to all animals are present. Introns are actually more frequent in human genome. This suggests that some new unidentified degrees of freedom giving rise to complexity might be present and that the chemistry of DNA in the sense of standard physics is perhaps not all that is needed to understand genetic program.

5. Various self-organization process such as self-assembly and de-assembly are very frequent in living systems. The problem how genes give rise to morphology of the organism is poorly

understood. This forces to challenge the dogma of genetic determinism. One should be able to understand what is determined by genes what is determined by self-organization and whether the genes of the standard physics are enough.

The reason why the above mentioned problems have turned out to be so intractable might be due to a wrong view about space-time. Many-sheeted space-time concept of TGD might be absolutely crucial for the expression of genetic code. DNA itself might involve many-sheeted space-time structures coding faithfully the topology of the body parts. This many-sheeted structure of DNA could allow to understand the miraculous looking features of DNA replication and differentiation of cells. TGD based view of evolution as p-adic evolution implied by the basic quantum theory, should be a crucial element of the picture. Together with the p-adic length scale hypothesis it leads to precise quantitative predictions and a general model for genetic program based on the many-sheeted space-time concept. The model explains also why introns are present only in eukaryotic genome. Most importantly, it seems that the statements represented by the dynamical intron-exon decompositions of genes and defining Boolean algebra, could represent our conscious beliefs and thus affect our behavior as conscious beings. Notice the beautiful connection between matter and mind: genes code the information, not only about the material structure of organism, but also about its belief system. Thus without introns, the pariah class in the society of biomolecules regarded as "junk DNA" by always-so-imaginative reductionistic materialists, we would have no world views and belief systems! In this chapter TGD based view about genetic code and its realization are discussed in detail.

9.1.1 Many-Sheeted DNA

The replacement of the DNA of standard physics with many-sheeted DNA suggest surprisingly simple model for how organism's morphology is coded and decoded to DNA.

1. How the morphology of body is coded?
   The most striking feature of DNA is its one-dimensionality. According to work of Mae-Wan Ho, living systems are liquid crystals [D3]. Liquid crystals are effectively one-dimensional since the layers of the liquid crystal consist of homogenous liquid phase determined by macroscopic characteristics such as pH, temperature, ionic concentrations and electric fields. This suggests that the structural information coded into DNA could be essentially information about the macro- properties of the layers of liquid crystal. This would make 1-dimensional coding of the body plan using DNA sequences very natural. Kind of contraction of the body parts to DNA sequences having many-sheeted structure could be in question! This coding would preserve the topological structure of the many-sheeted space-time surface representing the expression domain of the gene. The structure of the expression domains of maternal genes and Hox genes [I130] controlling morphogenesis supports this picture.

2. How DNA is expressed?
   The very naive first guess is that during growth various thin space-time sheets associated with DNA gradually grow and are glued together by the join along boundaries contacts and form the space-time sheets associated with their expression domains. Somewhat exaggerating, many-sheeted DNA would represent only a particular developmental period of organism in which it is contracted to a thin thread. For instance, the cells determined to develop into eye are glued to the space-time sheet representing future eye and replication products belong also to this space-time sheet. Clearly, the gluing to the space-time sheet of the future expression domain would generate the needed long range correlation between cells in the expression domain. It must be emphasized that self-organization should play key role in this process: for instance, liquid crystal nature of the living matter should determine morphology to a high extent.

3. What makes differentiation and control of the morphogenesis possible?
   Differentiation must be explainable as a selective activation of transcription and although a local process, involves also top-down control making possible a precise timing. Concentration gradients for the transcription factors, that is proteins controlling transcription, are

certainly crucial in this respect. When the concentration of the protein falls below a critical value, the truth value of a statement representing input to some gene program modules changes. This leads obviously to spatial patterns of gene expression resulting from branching of gene programs. For instance, the development of organs should result as a combination of genetic control of this kind plus self-organization. Join along boundaries bonds between gene space-time sheets and larger space-time sheets or genes and control regions of chromosome make possible quantum control of genetic expression based on phase gradients of the super conducting order parameters and resonant Josephson frequencies which correspond to magnetic transition frequencies of genes, control regions or related substructures. It could also be that the # contacts (wormhole contacts) from genes to various space-time sheets representing body parts provide the interaction with the classical fields of the macroscopic space-time sheets representing body arts and controlling the activity of a particular gene. In any case, the fact is that the action mechanisms of transcription factor proteins in eukaryotes are not understood. The mechanism is not purely chemical one since transcription factors are often located quite far from the promoter region. Electromagnetic oscillations with resonant frequencies could be in question. In absence/presence of oscillation gene is activated.

9.1.2 Realization Of The Genetic Program

TGD suggests concrete ideas about how organism can act as a conscious computer [**?**] Genome represents possible statements consistent with a fixed atomic statement (single element set in set-theoretic representation of Boolean algebra) represented as sequences of DNA. DNA triplets define basic axioms of the axiom system in question. Active genes which have coded some minimum about of intronic mRNA and protein coded by the exon part of the gene give rise to conscious experience about the truth of the statement represented by the gene. Otherwise the truth value of this statement is ill-defined and not consciously experienced. Truth values of the statements representing conclusion of the statement represented by gene in turn act as premises for the statements represented by some genes and these genes in turn activate and give rise to experience of the truthness of corresponding statements. In this way genetic program proceeds and gives rise to a sequence of experiences about truthness of statements represented by the genome. Note however that the experiences of truthness at DNA level need not correspond to our conscious experiences: entire hierarchy of selves having connection to DNA level is involved.

The beautiful feature of this realization of genetic program is that no cables for signal transmission are needed. The genetic program is also extremely robust and flexible unlike ordinary symbol based programs in which the change of the value of single binary digit can lead to a catastrophe. Furthermore, spatial patterns of gene expression develop naturally: gene in give cell producing transcription factor affects only finite region of space since subcritical concentration of the transcription factor means effectively its total absence. This can lead to intricate structural patterns of gene expression and determination of cells making possible differentiation. The translation of average protein requires 20-60 seconds and the cognitive processes of ours which possibly occur at DNA level must be rather slow. Time scale of emotions is however slow as is also higher level abstract thinking.

Both introns and exons represent statements which are true if the premises of the gene statement are true. Simple model for how introns can be separated from the exon part of the genetic module explains the many mysterious properties of introns elegantly and introns become an absolutely essential element of the genetic program. In particular, addition or subtraction of a marking - "comment sign" - to nucleotide changes the nucleotide from exonic to intronic or vice versa. Thus this marking serves essentially as a binary digit telling whether nucleotide belongs to exon or intron. Unless physical realization of these markings poses any additional constraints, comments signs can be dropped anywhere in gene and this means that same gene can be expressed in 2^N way, where N denotes the number of basic units in the maximal decomposition into exons and introns. Obviously, an interpretation as a representation for the statements of Boolean algebra for statements about N basic statements suggests itself strongly: perhaps each eukaryotic gene represents Boolean algebra! If also intron-exon decomposition is assumed to be dynamical then

the number of exon-intron decompositions in gene consisting of N DNA triplets is

$$M = \sum_{k=1}^{N} \left(\begin{array}{c} 3N \\ 3k \end{array} \right) \quad .$$

The premises of the gene statements are represented in the operator sequences associated with the gene. Intron $\leftrightarrow$ exon transformation induced by the addition or cancellation of "comment signs" associated with nucleotides leads to a generalization of the operon model for the regulation of gene transcription. The protein coded by introns which have become an exon part of gene serves as a repressor of the gene expression for original exons. The shifting back to a mode in which exons are coded to protein means that the coding of the supressor protein stops and the genes whose activation depends on the output of the gene in question are automatically activated.

A cautious proposal is that many-sheeted genes could represent a hierarchy of conscious beliefs: genome would be a collection of Boolean algebras represented by genes. In case of prokaryotes these Boolean algebras contain only one expressed element; in case of eukaryotes number of elements can be much larger but again totally intronic gene is not expressed. Maybe DNA could code thoughts and proteins emotions associated with them.

9.1.3 Are Non-Chemical Transcription Factors And Non-Chemical Gene Expression Possible?

Enhancers and silencers affect gene expression in a non-local way difficult to understand purely chemically. There are also tissue specific transcription factors. The notion of many-sheeted DNA suggests the possibility of non-chemical transcription factors. Classical em and Z^0 fields are especially interesting possibility as far as gene expression and its control in long length scales are considered. The general quantum control and coordination mechanisms based on Josephson currents flowing between gene space-time sheets and larger space-time sheets and making possible comparison circuits, clocks, alarm clocks and novelty detectors, suggest themselves. Indeed, the frequency scale 20 amino-acids per second for the translation process corresponds to a typical scale for the magnetic transition frequencies, which lie at the heart of the TGD based theory of brain consciousness. Classical fields affect various macroscopic quantum phases and one cannot exclude the possibility that gene level is involved with cognition and sensory experiencing even in the time scales shorter than the long time scales associated with the neural transmitter action.

Neural level could control genetic level (this is known to occur chemically) via non-chemical control mechanisms. Nuclear matrix, cytoskeleton and the collagen network associated with connective tissues are liquid crystals and ideal tools for transforming electrical signals to mechanical (say conformational wave s) and vice versa. The massless extremals associated with the microtubules connecting neuronal cell membrane with the nuclear region could make possible the information transfer from neural level to gene level: in fact, the non-dispersive vacuum currents associated with the massless extremals are optimal for communication purposes. This suggests that nerve pulse patterns could be transferred into genome along cellular matrix.

The idea that information from the genetic level would be transferred to neural level and that genetic level could even control neural level chemically is consistent with experimental facts. One could even consider the possibility that genome plays the role of neuronal brain. One can indeed play with idea that possible "this is true" experiences associated with the active genes could be expressed as our emotions. As noticed, the time scale of chemical gene expression is .05 seconds and is much slower than the millisecond time scale of nerve pulse so that direct translation of genes to nerve pulse patterns is not plausible. This is however consistent with the realization of "this is true" experiences as emotions which are characterized by slow time scales. Thus the statements "If A then B" expressed by genes B and the control structures A associated with them could give rise to neural activity translating these experiences to sensory experiences about the internal state of brain accompanied by and often identified with emotions, which in turn could be expressed as internal speech. Music metaphor does not however require any precise coding to nerve pulse patterns. The idea that this communication could occur also non-chemically is much more speculative and not actually supported by the most stringent form of the master slave hierarchy. It is also difficult to imagine how the coding of DNA sequence to, say nerve pulse patterns, could

be achieved. In principle, memetic code could be realized as sequences of 21 DNA triplets. The idea about direct one-to-one mapping of DNA level to memetic level seems however implausible.

The large amount of silent DNA suggest that some non-chemical gene expression mechanisms might be at work. This does not necessitate communication between genomes although also this is possible in principle. The extreme would be that neuronal genomes could form neuronal democracy communicating to each other their "If A then B" opinions with conclusion B depending on what the exon-intron decomposition of gene B is for particular gene. This would make possible neuronal voting. Assume that the sub-selves of self are neuron groups with identical synchronized inputs A. This means that same genes are activated and output depends only on the intron-exon decomposition of the individual gene and that sub-self experiences entire spectrum of opinions about what A implies. Self experiences the neuron group sub-self as the average over the opinions "If A then ..." of individual genome subsub-selves. One can also consider the possibility of Boolean "machines". Gene B receives the premises A of "If A then B" as nerve pulse pattern acting to the control sequence associated with B and generate as output the nerve pulse pattern representing statement B when premises are satisfied.

9.1.4 Model For The Genetic Code

The basic numbers of genetic code are probably not accidental. This led for ten years ago to an attempt to construct a model for abstraction process reproducing the basic numbers of the genetic code. The simplest model for an abstraction process is based to a repeated formation of statements about statements starting from two basic statements. If one drops at each step of construction the statement corresponding to empty set in the set theoretic realization of Boolean algebra, one obtains a hierarchy allowing to understand the basic numbers of genetic code.

What one obtains is so called Combinatorial Hierarchy [**?**]onsisting of the Mersenne numbers $2, M(1) = 3, 7.127, 2^{127} - 1, ..$ constructed using the rule $M(n+1) = M_{M(n)} = 2^{M(n)} - 1$. The explicitly listed ones are known to be primes. Combinatorial Hierarchy emerges from a model of abstraction process as subsequent transitions from level to meta level by forming Boolean statements about Boolean statements of level n and dropping one statement away. Combinatorial Hierarchy results also by constructing the sets of all subsets with empty set excluded starting from two element set. The set of statements at level n can be given a structure of Finite Field $G(M(n), 1)$ if $M(n)$ is prime. The multiplicative groups $Z_{M(n)-1}$ form a nested hierarchy and the coset spaces $Z_{k_n} \equiv Z_{M(n+1)-1}/Z_{M(n)-1}$ are cyclic groups. Combinatorial Hierarchy based model of Genetic Code explains the number of DNA:s and amino-acids and the representation of words of the GC as triplets of 4 different codewords. Aminoacids correspond to $k_{n=3} = 21$ axioms of a formal system defined by $n = 3$ level of Combinatorial Hierarchy having a unique imbedding as the group $Z_{k_n} \subset Z_{M(n)-1} = Z_{126}$ and DNA:s correspond to the set $X_{N(DNA)} \subset Z_{M(n)-1}$ of $N(DNA) = (M(n)+1)/2 = 64$ statements consistent with a given atomic statement at level n regarded as special cases of general theorems. GC corresponds to the mapping $x \to x^{k_{n-1}} = x^6$ in $Z_{M(n)-1}$ mapping DNA type statements to amino-acid type statements. The numbers of DNA:s coding single amino-acid are reproduced in a symmetry breaking mechanism involving the finite groups $Z_{p_{n-1}}$ and Z_{k_n} and symmetry breaking is in a well defined sense minimal. The infinite hierarchy of possible genetic codes suggests the possibility of an infinite hierarchy of increasingly complicated life-forms.

The physical model of the genetic code leads to a beautiful interpretation of the genetic code as mapping the fundamental 64 truths to 20 basic conscious experiences, perhaps the emotion about truthness. The fact that hormones correlate with emotions suggests that this map assigns to a logical statement an emotion and that even our emotions could relate to DNA level. Note however that TGD predicts entire hierarchy of selves. Aminoacid P corresponds to the emotionally experienced truth $G_1(P)$ or $G_2(P)$.. or $G_n(P)$ is true, where G_i code for protein P. 3 stopping sign codewords cannot be experienced emotionally as truths not non-truths (holy trinity!).

9.1.5 The Relationship Between Genetic And Memetic Codes

TGD leads to a model of Boolean mind in terms of the temporal sequences formed by cognitive neutrino pairs with vanishing total energy. As noticed, the model for abstraction process predicts entire hierarchy of genetic codes [**?**] This leads to the idea that our cognition might correspond to

the level next to the genetic code. The hypothesis that memetic code corresponds to the next level of Combinatorial Hierarchy characterized by Mersenne prime $M_{127} = 2^{127} - 1$, when combined with p-adic length scale hypothesis, leads to a prediction of about .1 seconds for the duration of the "wake-up" period of sub-self corresponding to the codeword of the memetic code.

The memetic codeword consists of 126 bits and could be represented by two possible spin directions of fermion corresponding to two values of Boolean statement. This implies that one millisecond should be the duration of single bit: this time scale is indeed fundamental for nerve pulse activity. What the fermions in question are? Ths question must be left open. The original proposal based on cognitive neutrino pairs at opposite throats of wormhole contact discussed in [**?**]ooks highly unrealistic from the point of view of standard model physics. The possibility of scaled variant of weak interaction physics with intermediate boson length scale of order cell size or cell membrane thickness however allows to consider this kind of option. Dark protons is another assignable to the lipid layers of cell membrane is second option [**?**]

This picture suggests the following general framework. Memes and genes correspond to two levels in the hierarchy of conscious intelligence and genetic programs could be perhaps seen as subprograms called by the higher level memetic programs. One could even see higher level life as symbiosis of memes and genes.

This raises several questions. Does genetic code determine the evolution of the organism or is the development of organism some kind of "social process" in which the genetic level interacts with the memetic level? Do genes code the space-time sheets representing the hardware of the memetic level or do higher level organisms represent symbiosis of two almost independent life forms? Does memetic level control genetic level or vice versa or is the interaction between these levels bi-directional? Despite that these questions which remain open, it seems that the three approaches to understand cognition based on the Combinatorial Hierarchy model of abstraction process, to fermionic Boolean algebra as a model of logical mind and to genetic and menetic programs as a model for conscious intelligence seem to combine to form single "holy trinity" of cognition.

9.1.6 Mersenne Hypothesis

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

The hypothesis that Mersenne primes $M_k = 2^k - 1$, $k \in \{89, 107, 127\}$, and Gaussian Mersennes $M_{G,k} = (1 + i)k - 1$, $k \in \{113, 151, 157, 163, 167, 239, 241..\}$ (the number theoretical miracle is that all the four scaled up electronic Compton lengths with $k \in \{151, 157, 163, 167\}$ are in the biologically highly interesting range 10 nm-2.5 μm) define scaled up copies of electroweak and QCD type physics with ordinary value of $\hbar$ and that these physics are induced by dark variants of corresponding lower level physics leads to a prediction for the preferred values of $r = 2^{k_d}$, $k_d = k_i - k_j$, and the resulting picture finds support from the ensuing models for biological evolution and for EEG [**?**] This hypothesis - to be referred to as Mersenne hypothesis - replaces the earlier rather ad hoc proposal $r = \hbar/\hbar_0 = 2^{11k}$ for the preferred values of Planck constant. The background necessary for understanding what is involved is described in [**?**]

9.1.7 Fractal Hierarchy Of Magnetic Flux Sheets And The Hierarchy Of Genomes

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

1. The quantization condition for magnetic flux reads in the most general form as $\oint(p-eA)\cdot dl = n\hbar$. If supra currents flowing at the boundaries of the flux tube are absent one obtains $e\int B\cdot dS = n\hbar$, which requires that the scaling of the Planck constant scales up the flux tube thickness by r^2 and scaling of B by $1/r$. If one assumes that the radii of flux tubes do not depend on the value of r, magnetic flux is compensated by the contribution of the supra current flowing around the flux tube: $\oint(p-eA)\cdot dl = 0$. The supra currents would be present inside living organism but in the faraway region where flux quanta from organism fuse together, the quantization conditions $e\int B\cdot dS = n\hbar$ would be satisfied.

2. From the point of view of EEG especially interesting are the flux sheets which have thickness $L_e(151) = 10$ nm (the thickness of cell membrane) carrying magnetic field having strength of endogenous magnetic field. In absence of supra currents these flux sheets have very large total transversal length proportional to r^2. The condition that the values of cycloctron energies are above thermal energy implies that the value of r is of order 2^{k_d}, $k_d = 44$. Strongly folded flux sheets of this thickness might be associated with living matter and connect their DNAs to single coherent structure. One can of course assume the presence of supra currents but outside the organism the flux sheet should fuse to form very long flux sheets.

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

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

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` [L19].

9.2 Background

The foundations of genetics were discovered by George Mendel in 1866, but remained generally unknown until 1900. During the first half of nineteenth century it was gradually realized that genes play major roles in the functioning and evolution of organisms. The discovery of DNA revealed the principles of heredity and how genes store hereditary information and transmit it from generation to next. Hereditary information is contained within the nucleotide sequence of DNA.

Organization, expression, and evolution of the hereditary information are the main aspects of genetics. Hereditary information is organized into chromosomes consisting of DNA sequences. It is expressed via transcription to mRNA followed by a translation to protein. The evolution of the hereditary information involves basically sexual breeding in one chromosome from the chromosome pairs of both parents combine to form chromosome pair. Also recombination of the members of the chromosome pairs is possible during meiosis. Also other mechanisms, such as fusion or fission of chromosomes and modification of DNA sequences, are possible. There are excellent books about topics [I76] but for the convenience of the reader the basics of genetics are very briefly summarized in the following.

9.2.1 DNA And RNA

DNA add RNA provide a way to store and organize genetic information [I76].

1. Genetic information is stored in nucleic acids, which are long sequences of nucleotide serving as letters of genetic code: three nucleosides form single world of code. There are four different nucleotides so that the number of different words is 64.

2. Nucleotide consists of three basic units joined by covalent bonds: nucleotide= nucleoside+sugar+$5'$-phosphate. The units are sugar, which is deoxiribose in case of DNA and ribose in case of RNA, phosphate and nucleoside (nucleic acid). Nucleosides are the information carrying part of DNA and RNA.

3. DNA and RNA sequences contain 4 different nucleosides. In case of DNA they correspond to C(ytocine), T(ymine), A(denine) and T(ymine). In case of RNA T is replaced by U(racil). U, T and C are purines containing one carbon ring and A and G are pyrimidines containing two carbon rings.

4. DNA molecules/nucleic acids/polynucleotides are formed as very long sequences of nucleotides bound together by phospho-diester bonds.

DNA double helix consists of two DNA strands, which are conjugates of each other, conjugation being defined as $A \leftrightarrow T$, $C \leftrightarrow G$. The helices are bound by hydrogen bonds between A and T and C and G respectively.

Sequences of DNA triplets form genes, which represent basic units of hereditary information revealed as traits of the organism. Each gene involves also additional DNA sequences serving as control structures in the transcription of gene to mRNA. In prokaryotes there is only single chromosome in the form of a circular double strand. In eukaryotes the chromosomes are located in nucleus and appear in homologous pairs. Eukaryotic chromosome is a complicated helical structure resembling beads in thread formed by DNA. DNA is wound around nucleosomes with diameter $d \simeq 10$ nanometers. Nucleosomes consist of octamer formed from 4 different histones. Chromosome structure will be considered in more detail later.

RNA appears both inside nucleus and cell. There are several types of RNA.

1. Messenger RNA (mRNA) is the outcome of transcription of DNA inside nucleus and is translated to proteins outside the nucleus.

2. Transfer RNA (tRNA) is involved in the translation of mRNA to protein: tRNA molecules bind specific amino-acids and glue them to specific mRNA triplets in a way dictated by genetic code. rRNA appears as a building block protein of ribosomes playing the role of reading head in the translation of mRNA to proteins.

3. In case of eukaryotes transcription involves intermediate state in which DNA is transcribed to hnRNA which contains also the transcriptions of introns ("junk DNA"), which are split in so called splicing process cutting away intron RNA to form RNA-protein complexes which remain inside nucleus.

9.2.2 Proteins

Proteins are in a vital role in organisms. The diversity and complexity of life is largely due to the diversity and complexity of proteins. Some proteins act as transcription factors controlling genetic expression. Some proteins are used by cells in chemical communication between cells: hormones serve as signalling proteins; various receptor proteins serve as receptors of chemical signals and hormone-receptor complexes serve as transcription factors. Neural transmitters appear in the synaptic communication between neurons. Some proteins act as enzymes catalyzing biochemical reactions. Other proteins serve as structural building blocks, either by themselves or in association with nucleic acids (nucleoproteins), polysaccharides (glycoproteins) or lipids (lipoproteins). Some proteins, such as myoglobins and hemoglobins are associated with metal-containing organic molecules.

Proteins consists of polypeptides, which are polymers of 20 different amino-acids. Genetic code assigns unique polypeptide to a given gene. With single exception amino-acids share the same basic structure. Hydrogen atom H, carboxyl group COOH and amino group NH_2 and radical R linked to carbon atom. R determines exclusively the chemical properties of protein. 8 amino-acids are nonpolar (hydrophobic) and 12 of them are polar (hydrophilic). Of the twelve polar amino-acids 7 are neutral, 3 are basic (tending to become positively charged) and 2 and acidic (tending to become negatively charged) under physiological conditions. Carboxyl and amino groups tend to become ionized at physiological pH; -COOH group tends to lose its proton and NH_2 group tends to gain a proton.

In polypeptides, which are products of gene translation, amino-acids are linked to each other by peptide bonds formed when NH_2 group of one amino-acid and $COOH$ group of next amino-acid are linked (H_2O molecule is snipped away in this process). Polypeptide chains spontaneously adopt so called secondary structure determined by the nature of the R groups along the backbone. Backbone forms alpha helix, a coil containg 3.6 amino-acid redidues per turn. Another secondary structure is the beta pleated sheet configuration consisting of rows of polypeptide chains hydrogen bonded with each other. Polypeptide can also adopt the form of a random coil. Proline, because of its unique structure, causes a kink in the polypeptide backbone. Polypeptides have also tertiary structure. How the tertiary structure is determined by the chemistry of amino-acids is poorly understood. One of the big problems of biology is to understand who protein is able to fold to such a unique configuration. TGD suggests that tertiary structure might not be determined solely by the standard chemistry and that many-sheeted nature of protein might be crucial in determining the final result of the folding. There is also quaternary structure associated with proteins formed by polypeptide sequences. The formation of higher level structures, such as micro-tubules, micro-filaments, cell membranes and collagen fibers involves self-organization and living matter seems to behave as a liquid crystal whose basic properties depend only on very general properties of protein.

9.2.3 Replication, Transcription, Translation

Information processing in living matter involves three basic processes: replication, transcription and translation. Replication of DNA means replication of DNA double helices and is essentially copying of genetic information. Replication involves unwinding of the parental strands of DNA double helix. They serve as templates on which the growing complementary daughter strands are synthesized. The direction of the synthesis is opposite for the two strands and only the second (leading) strand can be synthetized continuosly whereas the synthesis of the second strand occurs discontinuously and results in disjoint pieces of DNA containing approximately 1000 nucleotide pairs (Okazaki fragments of length about 34 nanometers), which later combine to form connected DNA strand.

DNA can be transcribed to mRNA molecules (messenger RNA) translated to proteins; to tRNA (transfer RNA), which is the RNA molecule affecting the coding of RNA triplets to amino-acids and to rRNA, which is the building block of the machinery affecting the translation. In case of prokaryotes the transcription of DNA to mRNA occurs directly. The rules for the transcription are

$$\begin{aligned} A \to U \ , \quad T \to A \ , \\ C \to G \ , \quad G \to C \ . \end{aligned}$$

In case of eukaryotes the transcription involves two steps since eukaryote genes in general decompose into exons translated to protein plus introns.

First the entire gene is transcribed to hnRNA sequence. After this so called splicing occurs and gives rise to mRNA, which corresponds to the DNA sequence formed by the exons. In the splicing process intron sequences are split off and wind around specific proteins which do not leave the nucleus. There are different pathways for slicing meaning that the decomposition to exons and introns is not unique. Dynamical exon-intron decomposition is essential for the working of immune system.

Transcription is a complicated process involving the action of several enzymes. RNA polymerase I is involved in the transciption of large rRNA molecules, RNA polymerase II with the transcription of hnRNA, RNA polymerase III with transcription of small 5S-rRNA molecules and tRNA molecules. Usually so called heavy strand is transcribed. Light strand can be transcribed

to some tRNA molecules at least. Gene is preceded by AUG triplet. In eukaryote cells RNA polymerase II copies sequences containing 6000-8000, sometimes even 20.000 nucleotides. The average length of mRNA sequence is 1500 nucleotides and the amino-acid corresponds to a sequence of average length of 1200 nucleotides.

RNA II polymerase binds to the promotor region preceding the gene. Promotor region contains at least two binding sites, so called TATA block and CCAT sequence regognized by RNA polymerase. Between promotor site and gene are operator site in which repressor enzymes bind and make translation impossible. TAC sequence denotes the beginning of that part of gene which is translated to protein (apart from introns). At the end of the gene there is rather long $A \cdots AAA$ control sequence preceided by TGA sequence signifying the end of the part of the gene to be translated. Introns which are not translated begin with AC and end with CA.

The translation of mRNA to polypeptide occurs outside the nucleus. Translation involves tRNA molecules, which are about 80 nucleotides long. Each tRNA contains a specific triplet which is anticodeword for the corresponding codeword in mRNA and binds only to this codeword in translation process. Each tRNA molecule binds with a specific amino-acid molecule and each amino-acid has at least one tRNA binding to it. The allowed bindings of tRNA and amino-acid molecules define genetic code. In translation tRNA carrying amino-acid attaches to an mRNA codeword to its own anticodeword and the amino-acid forms a peptide bond with the polypeptide sequence already translated at rRNA.

Genetic code assigns to 64 RNA triplets 20 amino-acids so that there is a considerable degeneracy involved. The largest number of DNA codewords mapped to same amino-acid is six. Three codewords are interpreted as stoppping sign for the translation. Genetic code is universal for the nuclear DNA of all eukaryotes and prokaryotes. The mitochondrial genetic codes of various eukaryotes however differ slightly from the universal genetic code. For instance, 4 DNA triplets can correspond to stopping sign.

Replication, transcription and translation are not the only information transfer processes occurring in living matter.

1. Reverse transcription $RNA \rightarrow DNA$ is known to occur in some cases and is also involved with the homing phenomenon of introns. Reverse transcription might have led from a system of RNA and proteins to system involving DNA sequences and primitive form of genetic code. The simplest starting system of this kind would consist of DNA coding RNA coding a protein which catalyzes both transcription and reverse transcription. This kind of system might have gradually evolved to a more complex DNA sequences.

2. RNA replication can occur in cells infected by viruses. What happens is that viral RNA strand which can be either single or double stranded, is replicated to its complement which in turn serves as a template for the synthesis of progeny RNA molecules.

3. Direct translation of DNA to protein without transcription has been observed only in vitro. This process probably never occurs in living cells.

9.2.4 Introns, Pseudogenes, Repetitive DNA, Silent DNA

The genes in nuclei of the eukaryote cells contain introns, sequences consisting of 10-1000 nuclotides interspersed with the exon parts of DNA which is translated to a protein coded by gene [I29] . Molecular Darwinist could compare introns with the commercials appearing between TV program or simply as selfish DNA. One could see them also unused parts of a computer program separated from the program code by comment signs in front of each line corresponding now to DNA nucleotide. The latter metaphor is consistent with the observation that intron can begin even in the middle of DNA triplet and that the transcription to mRNA is not unique so that same gene can give rise to several proteins. The content of intron sequences seem to be unrelated to the exon sequences: as if two separate interspersed computer codes would be in question.

Only one prokaryote cell, photosynthetic cyanobacterium Fischerella, is known to contain introns [I29]. Usually also the genes of cell organelles (such as mitochondria of human cell) contain only very few introns. Fungi are however an exception in this respect [I76]. The higher the evolutionary level of the eukaryote cell, the higher the fraction of introns in the genome is. For humane genome the fraction of exons is about one per cent. During transcription both introns and

exons are transcribed to hnRNA, intron sections are snipped away in a process called splicing and the resulting mRNA for the protein coded by exons is transferred from the nucleus and translated to a protein coded by the gene. It is possible to snip off the introns from genome but the mRNA coded by these genes is not transferred from nucleus, which suggests that introns have some role in genetic program. The addition of introns does not seem to have any dramatic effects on the genetic program.

Introns are a headache of molecular Darwinism. The nickname "junk DNA" tells the basic attitude towards introns. Introns represent selfish DNA living as parasites of the genome. There are two opposite schools concerning how introns have appeared.

1. The first school claims that introns came early. Somewhat surprisinly, this school sees bacteria as results of a long evolution which has gradually snipped off the introns from a primitive cell in order to achieve maximal rate of DNA transcription. One can of course wonder why the same thing has not happened to the cell nuclei also.

2. Second school tells that introns came late: this view conforms with the observations about the fraction of introns in genome. Introns seem to start from preferred sites and exons seem often to correspond to a modular decomposition of the protein they code. On basis of this it has been also proposed that introns separate modular parts of proteins from each other. The facts that introns can appear in the middle of protein module and even split single DNA triplet are not however consistent with this interpretation.

One can criticize the identification of introns as junk DNA.

1. It is difficult to see how human genome containing so high per cent of junk DNA could work with such a fantastic precision while viruses, second form of junk DNA, are often lethal. There are several pathways for slicing. Exon-intron transformation has been found to occur: exon and intron parts of gene simply change their roles [I29, I102] ! This suggest that exon-intron property is additional dynamical degree of freedom in genone and might have deep meaning. Exon↔exon transformation is indeed crucial for the working of immune system.

2. mRNA produced by intronless gene does not get out of nucleus. It seems that the presence of introns somehow initiates a module of genetic program taking care that protein mRNA gets out of the nucleus. Introns seem thus to be necessary for the functioning of the cell and could be in some sense regarded as an output of gene interpreted as a genetic subprogram. Note however that intron mRNA which winds around spherical proteins in the process of splicing, have not been reported to serve as transcription factors.

3. The positions of the intron sequences in similar genes are not same for various species. There are wandering introns which can move even from cell to another one. There is a phenomenon called homing [I29, I103]: the RNA coded by intron inserts itself into DNA sequence and builds by inverse transcription its complement in complementary DNA strand. In retrohoming intron transforms to RNA installed to DNA sequence by reverse splicing [I81] . This suggests that introns might provide a new mechanism for the evolution of the genome and provide a mechanism for modifying the program code of genetic programs. It is also known that there are long range correlations (in scale of one micro-meter) in genes containing introns [I112]. This suggests that introns are essential element in the organization of DNA to larger structures.

All these properties of introns suggest that their role in genetic program is badly misunderstood in the framework provided by molecular Darwinism and the basic dogmas of genetics.

Besides introns there are pseudogenes of various types, which by definition code no proteins. For instance, eukaryote genes from which introns have been snipped off, behave as pseudogenes. Pseudogenes can also contain "programming errors": for instance, the DNA triplet signifying the beginning of gene has changed. Genetic program metaphor suggests interpretation of pseudogenes as unused program modules. The idea about two interspersed program codes could explain the program errors as only apparent program errors. Of course, every experienced computer programmer would suggests the possibility of also genuine program errors! Also the interpretation as control structure affecting transcription via long range interactions rather than via chemical

contact interactions might make sense. It is indeed known that so called enhancers and silencers act as transcription factors in this manner.

Genetic code contains large amounts of repetitive DNA.

1. Five per cent of genome of the eukaryotes consists of highly repetitive DNA consisting of 5-300 nucleotides (even 10^6 copies are possible). In particular satellite DNA, containing less than 10 nucleotides belongs to this class. This DNA are active during mitosis and meiosis [I76].

2. 30 per cent of DNA is moderately repetitive. The first class corresponds to rRNA, 5SRNA, tRNA and histogenes (10-100 copies). These genes are concentrated in certain chromosomes. In case of genes coding rRNA, tRNA the repetition of genes is understandable since translation making possible large number of amino-acid copies does not occur. The fact is however that also genes coding proteins appear as very many copies and there is no obvious explanation for this. So called SINE segments have length not longer than 10^3 np and are interspersed through the entire genome as $10^4 - 10^5$ copies. LINE-segements consist about 3×10^3 np: there are about 10^4 copies are interspersed through the entire genome. Part of these sequences are transposons (see below).

3. 65 per cent of DNA are present in only few (1-15) copies. Both exons and introns belong to this group of DNA and exons form only one percent of human genome.

4. The control regions between genes are rather long and seem to contain DNA with no obvious function. Also second strand of DNA can be regarded as silent DNA since its presence is not absolutely necessary for the storage of genetic information. The question is whether this silent DNA has some hitherto unidentified function.

The genome of both prokaryotes and eukaryotes contains transposons, which are movable DNA sequences able to insert themselves to DNA with the help of insertion sequences. Insertion sequences are short (less than 2000 nucleotides) and do not code proteins. Insertion sequences can carry also promotor and repressor sequences with them. Transposons could be important for evolution.

9.2.5 Is Central Dogma An Absolute Truth?

The Central Dogma of molecular biology states that each gene corresponds to a unique polypeptid. There are several observations challenging Central Dogma.

1. It is known that many alternate pathways of transcript splicing are possible and give rise to different protein outcomes called isoforms. This would suggest that transformation of some introns to exons and vice versa occurs routinely in gene expression. Using computer program analogy, this transformation would mean that the program part represented by introns becomes active and the part represented by exons becomes passive.

2. The phenomenon of superimposed genes [I76]. There are genes nested inside genes and translation can start also in the middle of gene producing shorter protein than the gene usually. These phenomena were first observed for bacteriophage $\phi X174$, whose genome is known in its entirety. It is known that gene is transcribed as a whole and that different proteins result from frame shift. Gene can also overlap the DNA sequences formed by two subsequent genes as first observed in bacteriophage $G4$. These observations suggest that the standard notion of gene fails somehow.

3. It is known that also the "nonsense" strand of DNA can serve as template for transcription [I76].

9.2.6 Is Life Nothing But Biochemistry?

It is not at all obvious whether the hypothesis "life is nothing but biochemistry" holds true.

Organism	Human	Mus musculus	Amoeba	Marbled lungfish
$N(DNA)/10^9$	3	3	670	139
Organism	Salamander	Onion	Trumpet lily	
$N(DNA)/10^9$	81	18	90	

Table 9.1: The amount of total genome measured as the number of DNA triplets.

1. It is not known whether protein folding is coded into the chemistry of DNA. The problem is mathematically unattractable due to the occurrence of combinatorial explosion. It seems more probable that folding might be self-organization type phenomenon and thus affected by the conditions of environment: protein development can be regarded as hopping in spin glass type energy landscape leading to some deep valley of free energy valley. TGD suggest that folding is the quantum analog of this kind of process. In particular, p-adic length scale hierarchy and many-sheeted space-time concept (see **Fig.** `http://tgdtheory.fi/appfigures/manysheeted.jpg` or **Fig.** 9 in the appendix of this book) suggest that one cannot understand protein folding in terms of DNA chemistry alone.

2. DNA is essentially one-dimensional structure. This suggests that gene codes only one-dimensional skeleton of its expression domain and that self-organization by quantum jumps could take care of the rest. Indeed, the work of Mae-Wan Ho [I119] shows that living organisms are liquid crystals which can be regarded as one-dimensional crystals and two-dimensional liquids, whose properties can be characterized by some global parameters. Perhaps genes code the properties of various layers of the liquid crystal. One of the basic characteristics of liquid crystals is self-assembly and de-assembly. Depending on pH, ionic concentrations, temperature, electric fields, ... liquid crystals organize to micelle like structures (cell membranes, collagen fibers, ...) and effectively one-dimensional layered structures [D3].

3. One can wonder how morphology is coded in DNA and how it is decoded from DNA. It is not at all obvious that DNA chemistry, which is purely local, is enough to code morphology.

4. So called enhancers and silencers are transcription factors, which encourage or disencourage gene expression in eukaryotes. The position of these proteins or orientation in DNA does not seem to be important [I76]. For instance, they can bind to introns and the distance of the binding site from gene promotor regions can be thousands of nucleotide pairs. This would suggest that the mechanisms of enhancing and silencing are not purely chemical if chemical at all. This would suggest the generalization of the notions of gene expression and transcription factor. Chemical expression takes place very slowly. Non-chemical expression modes yielding non-chemical transcription factors could make possible very fast running of genetic programs and there could be even connection between many-sheeted genome and nerve pulse activity.

5. The naïve expectation is that the size of the genome should correlate with the evolutionary stage of the species. Eukaryotes indeed have genome which is typically 10^3 times longer than prokaroyote genome. The **Table 9.1** however shows that the total length of genome does not correlate with the complexity of the organism faithfully. The genome of plants is typically 10-100 times longer than human genome. The genome of amoeba is by two orders of magnitude longer than that of human! The genomes of monkeys and men are almost identical. This suggests that there might be some unindentified degree of freedom associated with DNA which explains these differences.

9.3 Many-Sheeted DNA

The notion of many-sheeted DNA suggest a profoundly new manner to understand how the morphology of the organism is coded to and decoded from DNA. p-Adic length scale hypothesis leads

to precise quantitative predictions for the number of levels of genetic program as function of a suitably defined size of the organ. The proposed model for introns leads to the interpretation of gene as a representation for Boolean algebra and to the proposal that genes realize not necessarily conscious-to-us Boolean mind at the basic level. What is especially nice is that connection with the realization of Boolean mind in terms of cognitive neutrino pairs is consistent with this picture. Many -sheeted DNA suggests also new forms of gene expression and of control of gene expression. For instance, nerve pulse patterns could affect also genetic program of postsynaptic cell via the classical em and Z^0 field patterns associated with them and genes could affect cell membrane via conformational waves propagating along micro-tubules connecting nucleus to cell membrane.

9.3.1 Many-Sheeted DNA As Hierarchy Of Genetic Programs

Many-sheeted DNA allows to realize genetic subprogram hierarchy in an elegant manner. Many-sheeted DNA and proteins are like a hierarchy of ordinary DNA and proteins effectively living in different space-times corresponding to body parts. One can consider the possibility that subprograms correspond to p-adic space-time sheets and subprogram hierarchy corresponds to the hierarchy of p-adic space-time sheets. The gene program in a given length scale would selectively activate programs in shorter length scale, etc.. DNA sequences with the same chemical structure correspond to different genetic programs since the many-sheeted structure of DNA affects its functioning. Analogous conclusion is true about proteins.

One can assign to gene a unique p-adic prime as the prime characterizing the largest p-adic sheet at which gene has # contacts. The number of levels in subprogram hierarchy could be deduced from the size of the organism. Gene can have # contacts to several space-time sheets characterized by p-adic primes $p \simeq 2^k$, k power of prime. Denote by k_G the largest value of k associated with gene. k_G characterizes the position of gene in subprogram hierarchy. Gene can have # contacts with space-time sheets $k < k_G$ also. Gene can be characterized by the p-adic k_G labelling the largest space-time sheet to which it has # contacts. "Comment sign" marking each nucleotide of intron could correspond to a direction of classical field at some space-time sheet characterized by p-adic prime $p \simeq 2^k$, $k = k_I$. The only sensible assumption seems to be $k_I = k_G$.

The other # contacts of gene must be assumed to be on space-time sheets with $k < k_G = k_I$. This implies that given program can call only programs which are in the lower level of the hierarchy. This would suggest that programs belonging at the lower level of hierarchy cannot call program at higher level. Does this imply that growth process in which larger and larger space-time sheets are activated can only occur by self-organization? This would mean that DNA space-time sheets with increasing value of k_G expand in phase transition like manner and fuse to form space-time sheets corresponding to various body parts. On the other hand, it is not at all obvious that growth process could not start from higher level and lead to gradual differentiation at lower levels. In fact, embryogenesis seems to occur in this manner [I76].

Also proteins can be classified by the number k_P characterizing the largest space-time sheet to which protein has # contacts. Proteins must mediate program calls to gene modules G_1 with various values of $k_{G_1} < k_G$. This suggests that protein activating gene characterized by k_{G_1} must have same $k_P = k_{G_1}$. This would automatically guarantee that chemically identical proteins activate only the genes belonging to the level of the fractal hierarchy they represent.

The notion of many-sheeted DNA has immediate applications.

1. Many-sheeted DNA provides a possible explanation for why DNA triplets act as codewords of the genetic code. If members of each DNA triplet are glued to space-time sheet containing only # contacts from the nucleotides of the triplet, codewords have a clear geometrical meaning.

2. The notions of many-sheeted DNA and many-sheeted protein suggests also an explanation for how enhancers and silencers are able to regulate gene expression. Interaction with classical em or Z^0 fields via wormhole contacts provides a non-chemical interaction mechanism. Second mechanism is based on Josephson currents running along join along boundaries contacts. Since interaction with much larger length scale is involved, these interaction mechanisms are not too sensitive to the position of the transcription factor and the distance of the binding site from gene promotor regions can be thousands of nucleotide pairs. This mechanism explains

also the observe issue specificity of some transcription factors. Proteins with same chemical structure can be quite different transcription factors if they have contacts to different space-time sheets.

9.3.2 Possible Answers To The Basic Questions

Many-sheeted DNA suggests stupifyingly simple coding of body's morphology. The genes would be obtained by simply contracting the many-sheeted space-time representing expression domains of genes to one-dimensional structure. Decoding of the morphology means the growth of this structures to their original size. Of course. this hypothesis is oversimplified but its extreme simplicity makes it worth of testing.

How the structure of expression domain of the gene is coded in the structure of gene?

The p-adic length scale of the gene correlates trivially with the p-adic length scale of the protein coded by it. Already protein folding implies that the correlation with the size of the structure coded by DNA is not so straightforward. Furthermore, proteins are not mere building blocks but can have quite abstract functions like regulating gene expression of genes.

Consider now various aspects of the idea that expression the domain of gene is coded into the structure of gene and this that correspondence could be also realized at functional level.

1. The first thing that comes into mind is that the p-adic length scale of the gene correlates with the p-adic prime of the space-time sheet which corresponds to the expression domain of the gene during early phases of the embryogenesis. Gene clusters, say Hox cluster, would represent kind of a miniature of the body and every gene of Hox cluster would give rise to a space-time sheet which would be a scaled down model of the expression domain of the gene. Thus the expression domains of various genes in the genome could correspond to the extended space-time sheets at the level of the genome and the topology of these genome level expression domains, in particular, their ordering, would be consistent with that for the actual expression domains. Expression domain corresponds most naturally to a join along boundaries condensate generated by the formation of the join along boundaries bonds between the extended space-time sheets associated with the genes. This means that the p-adic prime of the expression domain can be much smaller than one could conclude it to be on basis of its size.

2. One could test the hypothesis that the total length of the region occupied by gene and by the DNA controlling its activity in the genome could correlate with the size of its expression domain at the stage of the development when the gene is expressed. Note that many genes affecting morphogenesis are expressed in a very early stage: many of them in the embryonic stage when no cell formation has yet occurred. This stage corresponds to the p-adic length scale of a fertilized cell about 10^{-4} meters. Of course, the correlation between the content of the gene program and the size of its expression domain, is not necessary and might be even un-desirable.

3. Fractality suggests that the communication by expression factor proteins at the level of genome might mimic the hormonal communication occurring at the level of the entire organism. This could mean that the hormonal communication between the expression domains of two genes is equivalent with the presence of a transcription factor communication between corresponding genes at the level of nucleus. Hormonal communication between cells involves the formation of hormone-receptor complex acting as a transcription factor.

The length of human genes ranges to thousands of nucleotides. This would mean that the longest p-adic length scales of human gene would correspond to $L(173) \sim 16$ micro-meters. The total length of a human chromosome is about 75×10^6 DNA triplets. The corresponding p-adic length scale is $L(193) \sim 2$ cm. The next length scales correspond to the pair $(197, 199)$ and correspond roughly to the size of brain hemisphere and brain. The total length of DNA in chromosomes is $48 \times L(193) \sim 1$ meter, the size scale of human body.

Many-sheeted space-time concept suggests that genes actually correspond to DNA sequences glued to a larger space-time sheet defining the gene. Hox clusters could be one example of this.

The geometry of the organism might be coded to these secondary, tertiary, etc. space-time sheet structures of the DNA sequence guaranteeing the coding the topology of the body plan to the topology of the multi-sheeted DNA. These structures are be labelled by p-adic primes and their number would be quite limited.

The linearity of DNA suggests that also the plan of the expression domain should be essentially linear such that each cross section of each module of the expression domain is essentially homogenous phase and its structure is determined by a self organization process constrained by the p-adic length scale hypothesis rather than purely genetically. According to Mae-Wan [I119, I120] living systems are liquid crystals and the basic characteristic of the liquid crystals is that they have crystal like structure in one dimension and are liquids in transversal dimensions [D3] forming. thus layer-like structures. This suggests that p-adic self-organization determines the size of the transversal layer and that DNA only codes some general properties of the liquid phase for a given layer.

The sizes for the expression domains of the genes should form a hierarchy. Effective expression domain can be much larger than the p-adic length scale characterizing it since join along boundaries/flux tube condensates are possible. For instance, the modularization of the genetic programs of plants is perhaps stopped at the level $k = 167$ so that expression domains for plant cells could be regarded as join along boundaries concept of of $k = 167$ plant cells. At the level of organism this perhaps corresponds to the emergence of cell walls hindering the formation of higher level structures formed from cells: plant could perhaps be regarded as a large join along boundaries/flux tube condensate of $k = 167$ plant cells surrounded by a wall. Besides the length of the genome, the number of the p-adic hierarchy levels in the space-time sheet hierarchy of DNA is a natural candidate for a measure of the complexity of the organism.

How the information about morphology is expressed?

One of the fundamental questions of the developmental biology is how the information of genes stored into DNA is translated to the geometry and topology of the organism. The idea of many-sheeted DNA suggests an immediate answer to this question. Expression is "nothing but" the reversal of the coding. The expression domain of the gene contracted effectively to one-dimensional DNA-thread grows back to the expression domain with non-uniqueness and flexibility brought in by self-organization depending on external parameters. This means that various space-time sheets associated with DNA grow during grow to space-time sheets representing actual organs. This process involves the formation of flux tubes between growing space-time sheets associated with various DNA molecules so that coherent macroscopic quantum phases become possible.

One can ask how the growth plan is coded into DNA. Or how much of it is coded into the chemistry of DNA? The idea that DNA is essentially body contracted to a thin thread suggests that the chemical control of DNA is restricted to the local properties of tissues. The space-time sheets of replicating DNA at various body parts simply grow and fuse to form join along boundaries/flux tube condensates growing and giving rise to various organs. The replication of DNA would in turn be quantum self-organization process involving essentially self-hierarchy starting from atomic level and ending up the level of entire organism.

What makes cell differentiation possible?

Cell differentiation is one of the great mysteries of biology. It is known that only part of DNA is active in a cell located in a given part of body and that selective activation of the genome gives rise to differentiation. The problem is to understand the mechanism of activation. Especially difficult challenge for the view about life as mere chemistry is the interaction between large length scales with gene level making possible precise timing of genetic activity.

In TGD framework cell differentiation should correspond to a selection of branch in the flow diagram describing genetic program. This occurs during the growth since the concentrations of the proteins representing the inputs of the gene programs evolve during the growth and generate also spatial gradients. Therefore different branches of the genetic program are activated in different parts of the developing organism. Also the genes associated with space-time sheet of increasing size are activated during growth and this brings in new and higher control levels.

Very probably the mechanism involves interaction between microscopic degrees of freedom for DNA and between macroscopic degrees of freedom representing body part where DNA resides. The control and coordination based on Josephson currents between gene space-time sheets and larger space-time sheets is very probably involved as is suggested by the general time scales of genetic activity. Also the interaction with the classical fields of the space-time sheet of the body part to which DNA has wormhole contacts provides an obvious mechanism of activation. The frequencies of the coherent oscillations of em fields involved could be important in both interaction mechanisms. This kind of interactions with larger space-time sheets makes possible to understand induction phenomenon, which corresponds signalling between cells and entire cells groups. This kind of signalling could be crucially important for morphogenesis. Many-sheeted space-time thus provides explanation for the ability of cells to form organs. The notion of cell cohesion is introduced to explain this: the cohesion would correspond to the formation of join along boundaries/flux tube condensate of extended gene space-time sheets.

9.3.3 What Is The Number Of The Levels In Program Hierarchy?

The obvious idea is that the size of the organism determines the largest p-adic prime contributing to the program hierarchy. It is however not obvious whether to define the size of organism as the "physical", visible size or as electromagnetic size, which is well defined notion in TGD framework.

Does the visible size of the organism determine the number of hierarchy levels?

The simplest working hypothesis is that the number of the levels in the program hierarchy is the number of p-adic length scales between atomic length scale and body size. The larger the visible size of the organism, the larger the number of the levels in the genetic program hierarchy, if this hypothesis is correct. This number is testable characteristic of species and could be valuable guide in attempts to understand how genetic code functions. One can identify the hierarchical level of the gene by looking how many genes it activates before building block protein is coded. It must be however emphasized that visible size need not be a correct criterion: the point is that join along boundaries condensates are possible and give rise to a much larger body size than one might conclude from the value of largest p-adic prime involved.

It is instructive to look the numbers of hierarchy levels in some specific examples assuming that the visible size of the organism determines the number of hierarchy levels. It is assumed that $k = 139$ is the first level which counts as a hierarchy level.

1. Viruses could have 4 hierarchy levels if $k = 139, 149, 151, 157$. Proteins, lipid layers of cell membrane and cell membrane and genes coding building block proteins. It could be that only k=149 is present for the simplest viruses since the formation of the envelope is self-organization process.

2. Bacteria should have 5 levels. $k = 139, 149, 151, 157, 163$.

3. Home fly should have 12 levels since its size is below $L(197) \simeq 1.6$ cm.

4. Animals with size between $L(199) \simeq 16$ cm and $L(211) \simeq 10$ m have 15 hierarchy levels. Note the large gap between $L(199)$ and $L(211) = 64L(199)$.

5. The next level corresponds to the level of dinosauri and whales having sixteen levels unless they correspond to join along boundaries condensates formed from smaller structures which is quite possible. The next level is $L(223)$ and corresponds to size of 640 m!

Does the electromagnetic size of of organism determine the number of hierarchy levels?

There is a large gap between $L(199)$ and $L(211)$ and the next twin length scale corresponds to a length scale of one kilometer. This suggests that new levels of hierarchy possibly emerged after $L(199)$ cannot correspond to the physical growth of body. Mere large size does not guarantee intelligence. Furthermore, if the visible size of the organism determines the number of the hierarchy levels, then dinosauri would have been in a well defined sense more intelligent animals than we! These arguments suggest that the visible size of the organism need not determine the number of genetic program levels.

k	227	229	233	239	241
L_p/m	$2.5E+3$	$5E+3$	$2E+4$	$1.6E+5$	$3.2E+5$
k	251	257	263	269	271
L_p/m	$E+7$	$8E+7$	$6.4E+8$	$5E+9$	$E+10$

Table 9.2: Table of p-adic length scales above $L(211) \simeq 10$ meters. $L(151) = 10^{-8}$ meters is assumed.

1. It could be that DNA codes and even controls also the electromagnetic structure of the organism realized as topologically quantized electromagnetic field, "aura", characterizing the organism.

2. An alternative option inspired by the notion of memetic code, which is next level in the hierarchy of genetic codes predicted by the TGD inspired simple model of abstraction process, is that there are higher hierarchy levels present but they are not controlled by the genetic program but call it as a subprogram.

A natural working hypothesis is that EEG correlates with the electromagnetic size of the organism. EEG has emerged rather lately in the evolution and is possessed only by vertebrates. In case of humans it becomes fully developed only at the age of 18. Meditation in general tends to increase the amplitudes of low frequency waves with 8 Hz (alpha wave s) and also waves with lower frequencies (theta waves). This suggests that growth in electromagnetic degrees of freedom can continue all the lifetime and could be identified as what is called "spiritual growth". It could continue also after the physical death so that the protein based state of life would be only a part of much longer lasting process of self-organization analogous to the development of butterfly. Indeed, in TGD based picture about geometric time the death of the physical body does not mean the end of life.

Schumann resonances are resonances of em fields in the wave cavity defined by the 80 km thick layer between Earth's surface and ionosphere. The frequency range in question correspond to the frequency range of EEG. A hypothesis worth of considering is that human body generates via Schumann resonances topological field quanta, which define electromagnetic sub-selves having the size of Earth. One could even consider the possibility that the highest value of k_G depends on individual and people having tendency to have religious and mystical experiences have exceptionally large value of k_G.

The length scale corresponding to alpha waves is 3.8×10^7 meters and corresponds is roughly 3.75 times the length scale $L(251)$. If levels up to $L(257)$ are present in the human genome then the number of hierarchy levels is 22, not too large number. $L(251) \sim 10^7$ m corresponds to a frequency of 37.5 Hz and is quite near to the 40 Hz frequency claimed by Koch and Crick to be crucial for the visual consciousness! The frequency associated with $k = 257$ corresponds to the frequency of 5 Hz, which also belongs to EEG.

The electromagnetic size of the organ increases rapidly with the number of levels present in the hierarchy as **Table 9.2** demonstrates.

There are even more explicit observations about the importance of ELF em fields for the functioning of living matter and these observations finally led to a breakthrough in TGD based model of conscious brain. The observations about the special effects of ELF em fields on brain at cyclotron frequencies of ions Na^+, Cl^-, K^+ and Ca^{++} in endogenous magnetic fields $B_{end} = 2B_E/5 = .2$ Gauss were made already at 1983 [J14]. These experiments suggest that these ions/their Cooper pairs form are confined in the magnetic field of Earth and form bound states with macroscopic size of order cell size and with extremely small binding energy corresponding to frequency of order 10 Hz. This is impossible 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.

In many-sheeted space-time particles topologically condense at all space-time sheets having projection to given region of space-time so that this option makes sense only near the boundaries of space-time sheet of a given system. Also p-adic phase transition increasing the size of the space-time sheet could take place and the liberated energy would correspond to the reduction of zero

point kinetic energy. Particles could be transferred from a portion of magnetic flux tube portion to another one with different value of magnetic field and possibly also of Planck constant h_{eff} so that cyclotron energy would be liberated.

Also electron Cooper pairs of high T_c electronic super conductor as well as Cooper pairs of neutrino super conductor are important. Besides magnetic cyclotron frequencies Z^0 magnetic cyclotron frequencies and wormhole cyclotron frequencies make sense: Z^0 currents for ions indeed induce automatically also ionic currents.

One can argue that 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. Later the argument was modified the large values of Planck constant [K38, K35] imply that cyclotron energy scale is above thermal energy at room temperature even if thermal equilibrium of dark space-time sheets with ordinary ones is allowed. Also other ions are possible but these ions are especially important for nerve pulse generation. These super conductors must be effectively one-dimensional (otherwise gap energy is extremely small) and the needed confinement in the transversal degrees of freedom is caused by the presence of B_{end} which could be in TGD framework interpreted as the dark companion of the Earth's magnetic field responsible for controlling biomatter possibly also associated with the personal magnetic body. One could regard these super conductors as associated with the flux quanta of B_{end} having radius 25 μm (the size of a large neuron) by flux quantization and serving as templates for the formation of biostructures.

When the Josephson frequency (potential difference) associated with the weakly coupled super conductors of this kind corresponds to a magnetic transition frequency, quantum jumps between states of either super conductor occur and change the charge distributions and hence potential differences associated with other Josephson junctions associated with either super conductor. Quantum jumps can lead to "wake-up" of either or both super-conductor sub-self giving rise to a mental image. Also emission of ELF photons with resonance frequency is involved. The topological field quanta associated with these photons have typically size of order Earth's circumference. The fact that multiples of the cyclotron frequencies correspond directly to the most important frequencies of EEG and also to some important Schumann frequencies suggests very strongly that the "ELF selves" associated with these topological field quanta represent also selves in our self hierarchy. This leads to a general model for quantum control and for how the space-time sheets representing the self-hierarchy are coupled by join along boundaries bonds serving as Josephson junctions, to a detailed model for the quantum correlates of the sensory qualia and to a model of Boolean mind. ELF selves are a crucial factor of all these models [K42, K44].

The work of Michael Persinger shows that ELF em fields and ELF modulated em fields, affect also gene expression [J26]. Thus it seems that ELF levels, rather than being controlled by gene level, actually control and coordinate gene level rather via the formation of flux tubes between gene space-time sheets and ELF space-time sheet. Whether gene level actually *codes* also ELF levels of the organism is an interesting question. The idea about genome as the entire many -sheeted organism contracted to a thin thread would support this view. On the other hand, the notion of the memetic code identified as the next level of abstraction hierarchy suggests that ELF level corresponds to something genuinely new not reducible to gene level. ELF level could be even seen as a different life form next to the biological life living in symbiosis with biological life. One must also remember that higher levels could couple with gene level only via join along boundaries bonds/flux tubes and that the development of organism could be seen as a "social" process in the sense that growing organism gradually builds flux tubes to the space-time sheets representing higher level selves.

Whether the number of the hierarchy levels in the genetic program hierarchy is larger than the visible size of organism, might be perhaps tested sooner or later by deciphering the number of hierarchy levels in the genetic program. To check the hypothesis about EEG, it is enough to study simplest verterbrates possessing EEG. The identification the levels of various genes in program hierarchy would mean a tremendous boost in the understanding of genetic code and dramatic change in world view.

9.3.4 Band Structure Of Chromosomes As An Evidence ForMany-Sheeted DNA?

In prokaryotes DNA is arranged in single chromosome forming closed circular double strand whereas in eukaryotes DNA genome is organized into chromosome pairs. Chromosome is believed to correspond to single DNA thread which has beads in thread structure. Beads are spherical nucleosomes of diameter 10^{-8} meters ($L(151)$!) consisting of histones of 4 different types forming histone octamer. DNA is wound very tightly around nucleosomes, there is about 70 nanometers (slightly less than $L(157)$ of DNA per nucleosome. chromosome forms a helical coil with diameter found to be 30 nm. In interphase chromosomes are coiled once more to a hollow tube of diameter 200 nm (slightly less than $L(167)$) a helix of thickness about 10^{-7} meters. The transition from interphase chromosome to metaphase chromatid is accompanied by a winding to a helical coil of diameter about 600 nm (slightly more than $L(169)$). A possible interpretation of these transformations is as generation of new space-time sheets.

Chromosome banding was discovered already in eighteenth century by Metzner. Chromosome banding characterizes both the chromosome and the method used to produced the banding structure and there are many methods for revealing the band structure. Increasing resolution implies the division of band structures to smaller structures in fractal like manner. The band structures can be divided into two classes.

1. The highly localized heterochromatic bands, nucleolar organizers and kinetochores appear in all organisms. The latter two structures seem to reflect the purely geometrical organization, "packing", of genome rather than the internal organization of genome. The main features of heterochromatic banding are its universality, diversity and variability. Heterochromatic banding is present in all eukaryotes and can differ widely for closely related species and be very similar to widely different species. Heterochromatin seems to correspond to highly repetitive short DNA sequences of 10 nucleotide pairs (10^6 copies) located near the centromere of the chromosome. This DNA is not transcribed to DNA. Pairs are often duplicated and duplication leads to various physiological defects. Soma cells of some organisms appear to have ability to get rid of of heterochromatin whereas it is present in germ cells. These facts suggest that the regions of chromosome near its center regulate gene expression and that highly repetitive DNA sequences represent sites for genes at which repressor proteins bind. Abnormally large duplication of repressor sites would lead to stronger repression is more effective and could lead to abnormal development.

2. The chromosomes of the eukaryotes contain also non-localized bands called euchromatic bands. Patterns of euchromatic bands resemble closely to the patterns of DNA replication and patterns correlate very strongly with species. Thus euchromatic bands correspond to active RNA. The moderately repetitive DNA which is transcribed corresponds corresponds to euchromatin. It is known that there are several types of euchromatic banding. Band patterns can be used as diagnostic tools to identify various chromosome fusions and splittings. Various bands are of enormous value in providing manner to locate genes in genome.

In TGD framework a natural interpretation of various types euchromatic banding provide evidence for the many-sheeted DNA. Thus euchromatic banding should reflect the modular structure of the genetic program as well as the interspersing of control regions and transcribed regions of genes corresponding to the basic structure "If A then B" of the gene.

9.4 About The Notion Of Genetic Program

This section is devoted to a general discussion of several key ideas which were not available when I formulated the first TGD inspired vision about genetic programs and morphogenesis. The recent view about TGD inspired theory of consciousness and quantum biology allows much deeper formulation for the notion of genetic program. In particular, the vision about DNA as topological quantum computer allows to identify a possible role for the intronic portions of DNA.

9.4.1 What The Notion Of Genetic Program Could Mean?

How to define the notion of genetic program? As TGD inspired view about consciousness and living systems has evolved several several alternative definitions have emerged.

1. The first attempt to answer the question was inspired by the observation that so called Combinatorial Hierarchy might define a hierarchy of codes containing at least genetic code and what I christened as memetic code. The definition is based on the interpretation of DNA sequences - at least genes - as Boolean statements, which define axioms of a formal system which are identically true. The system in question corresponds to Mersenne prime M_7 containing 127 statements about which 64 is identically true and define the axions in question. Memetic code would correspond o M_{126} with 2^{126} axioms and could be realized as sequences of 21 DNA codons.

   The first proposed realization of the memetic code was in terms of temporal sequences of what I called cognitive neutrino pairs. It looks too nonsensical in the framework of standard physics and also in TGD framework it looks questionable.

2. With the advent of zero energy ontology (ZEO) came the observation that one could code "laws of physics" by zero energy states for which positive and negative energy parts of the state correspond to initial and final states for time evolution which conserves total fermion number and other charges. This would give rise to pairs of statements which are consistent with each other identifiable as rules expressed as superpositions of instances which are consistent with the rule.

3. DNA as topological quantum computer vision [K3] led to a considerable progress in the understanding of what genetic programs might mean. The basic idea is that the braiding of flux tubes connecting DNA nucleotides/codons to lipids of nuclear/cell membrane define natural topological quantum computation programs. It is natural to assign them with the intronic portion of the genome. These programs would define the software of the living matter whereas genes would define the hardware. The approach suggests a mapping of the letters A, T, C, G of the genetic code to u and quarks and their antiquarks. The discovery of what I call dark DNA realized as states of dark protons led to alternative realization of the sequences of DNA codons.

4. A deeper understanding of the anatomy of quantum jump in zero energy ontology led to a further insights [K23, K13]. In this framework the state function reductions to the opposite boundaries of causal diamond (CD) produce zero energy states with opposite inherent arrows of embedding space geometric time. These two reductions occur alternately and have interpretation in terms of sensory perception followed by motor action. This process occurs in all length and time scales and is not a property of only biosystems. Memories are represented as negentropically entangled states assignable to CDs and by Negentropy Maximization Principle [K60] they are approximate invariants and defined what might be called self representations or representation for the world. The braiding of the magnetic flux tubes is space-time correlate for the negentropic entanglement.

   The important outcome is that time reversal of memory representation can be interpreted as a plan or prediction realized in terms of braidings of the flux tubes. The interpretation of genetic program would be naturally in terms of the time reversed memories determining how, say, the seed of plant evolves to a plant. Dark photons are key element in the reading process and they can decay to ordinary photons with same energy identifiable as bio-photons. Biophotons give hopes of proving experimentally the existence of the template of the full-grown organism defined by its magnetic body and there is evidence that this kind of template indeed exists.

In the following the earliest proposals for what genetic programs might be, are discussed. These proposals can quite well be consistent with more recent views but are more formal and lack direct connection with the recent view about TGD inspired theory of consciousness and of living matter.

9.4.2 Genes And Genetic Programs

A possible model for the genetic program is based on the interpretation of DNA sequences as statements of a formal system. 64 basic statements represented by DNA triplets correspond to axioms which are identically true. Gene G is interpreted as a theorem of type "If I_1&....&I_n true then O_1&O_2...&O_n true" or generalizations thereof obtained by adding several input statements and allowing also negations of the input statements. It could be that complementary DNA strand represents statements of type "If I_1&....&I_n true then O_1&O_2...&O_n not true". If given DNA sequence has been translated to give rise to some minimum concentration of protein coded by it, the truthness of this statement is emotionally experienced by the genetic computer. Otherwise the truth value of the statement is ill defined.

The information about truth value of I_k is represented by the catalytic action of the enzyme coded by I_k on those parts of gene which are not transcribed, in particular on the promotor sequence of the gene. They give rise to experiences about the truth values of the statements $I_1...I_n$. The conclusion "O_1&, .., &O_n is true" represents the output of the gene. These statements appear as the premises for the statements represented by some other genes. Thus the running of genetic program represents a sequence of becoming conscious about various kinds of truths of the formal systems represented by genome.

Genes as statements of conscious formal system

The assumptions for the model of genes as statements of a conscious formal system are following.

1. DNA sequences are assumed to represent axioms of some formal system. There are 64 basic triplets of DNA, which correspond to basic independent statements, axioms, from which higher level statements are built using many-sheeted DNA making possible the construction of statements about statements about....

2. Genes are assumed to represent statements of type "If I_1&...&I_m then O_1&...&O_n true." or "If I_1&...&I_m then O_1&...&O_n not true." depending on which strand of DNA double helix is transcribed.

3. The output of gene is either true or ill defined gene can only be conscious about truthness of a statement or be unconscious. The logic of our conscious experience (which need not have anything to do with the possible gene level mind) is consistent with this. We can have conscious experience about truth values of a very limited set of statements and have no experience about the infinitely of all possible logical statements. Note that the experience with standard logic would suggest that the value of the statement is either true or false. The experience with ordinary computers would in turn suggest that the value of outputs could be true, false or ill defined.

4. Gene expression is the counterpart for the emotional experience about truthness of the statement represented by the gene. One can say that the output of the gene is true or ill-defined. The output of the gene G generated by gene expression appears as an input for those genes G_i, which represent statements whose premises depend on the statements appearing in the output of G. This implies that the evolution of the genome involves a sequence of conscious emotional experiences about truthness of some statements, which in turn make possible to become conscious about truthness of some other statements.

5. The formal system represented by DNA and many-sheeted DNA sequences has certain Gödelian flavor in it. The truthness of the stopping sign DNA triplets UAA, UAG and UGA cannot be expressed in terms of proteins coded by exons. They are like undecidable statements in an axiomatic systems whose truth value cannot be deduced from the axions. Introns however can contain stopping sign and if mRNA-protein complexes represent truthness of intronic statements, then it is possible to experience the truthness of also the statements containing stopping sign DNA. The analogy with "holy trinity" of mystic and religious thinking is obvious: whether "holy trinity" exists is not decidable by human means! Proteins clearly have finite expressive power. Given amino-acid coded by DNA triplets X_i tells only that the statement $\vee_i X_i$ is true so that the number of emotionally experiencable basic truths reduces to 20.

A more precise but less general model for genome as a conscious formal system is based on the following assumptions.

1. Exon part G of gene and its intron parts I_i are interpreted as logical statements G and I_i. Together they represent the conclusion of a theorem. Hence the running of genetic program means generation of a sequence of conscious experiences of type "*...then* $G_1\&...\&G_n$ is true" or "*...then* $G_1\&\cdots\&G_n$" is false depending on which DNA strand is involved in transcription.

2. The statement represented by a gene G is experienced to be true if G has generated some minimum concentration of the corresponding protein $P(G)$. Under what conditions the intronic statements $I_1,\cdots I_n$ are experienced as being true, is not clear. The basic dogma of genetics suggests that also now overcritical values for the proteins $P(I_i)$ translated from intronic mRNA inside nucleus make possible conscious experience about the truthness of these statements.

3. mRNA-protein complexes are not able to regulate directly the activity of genes having intron statements as premises. The regulation mechanism, if present, must be indirect. Simplest regulation mechanism is based on the observation that gene can be in states in which the roles of some introns and exons are changed. In particular, each gene has complementary gene for which exons and introns (with stopping sign excluded) have changed their roles. If the protein coded by complementary gene has the role of a silencer for the expression of gene protein, the production of mRNA-protein complexes means that the translation of the silencer molecules does not occur anymore. Since the existing silencer molecules gradually decay, these genes are activated. Thus the activation of a gene by intron-exon transformation activates automatically also the genes whose input depends on the output of the gene. Note that exons would code what is very much analogous to "printed output".

It is important to notice that cognition represented basically by a genetic program is not restricted to brain. All cells of body have DNA and elementary cognitive abilities. Perhaps the special role of the frontal lobes in cognition is due to the fact that DNA in cortex has wormhole contacts with topological field quanta representing electromagnetic part of our body not visible to bare eyes. The electromagnetic size of our body could be given the size of entire Earth as suggested by the fact that EEG frequencies correspond to Schumann frequencies associated with the resonances of the wave cavity between Earth's surface and ionosphere.

Genes as modules of a genetic program

Genes can be also regarded as modules of genetic program. The input of module consists of the premises of the statements $I_1\cdots I_n$ and conclusions represent the statements "$O_1\cdots ...O_n$ true" or "$O_1\cdots ...O_n$ not true". $O_1\cdots O_n$ serves as input for other genes and running of genetic program continues as long as premises of some genes are true.

Ordinary programs "If A then B" and "While A do B" as basic control structures. Also genetic program should have some control structures and it seems that both these structures appear in genetic programs.

1. Assuming that genes represent theorems, the general form of statements appearing in genetic program is indeed "If A then B". A is represented in terms of enzyme concentrations and possibly intron mRNA-protein complexes activating or repressing some genes. B is represented by the protein and intronic mRNA-protein complexes transcribed from gene.

   "While $N>0$ do $\cdots$ and $N\to N-1$" is the basic structure of loop in computer program. The simplest function of this loop is to circumvent infinite loops, which are nightmare of programmer. The counterpart of an infinite loop is member of species, which never dies. The presence of too many sufficiently intelligent (and, as one could bet, selfish) individuals of this kind would be a catastrophe from the point of view of species. It seems that this kind of condition is represented. Certain genes crucial for the survival of higher organisms contain certain amount of telomere which is reduced every time when the gene is active. This means that the gene modules effectively contain additional condition "While the amount of telomere $>0\cdots$ and reduce the amount of telomere by one unit".

One can understand basic rules of Mendel easily if the conditions guaranteeing the activity of gene depend on both members of chromosome. For instance, in the case that two traits are such that second on dominates, the output of gene realizing the property is logical AND function having as its arguments the truth values of the statements represented by related genes in the chromosomes. If G_1 in chromosome 1 and G_2 in its partner chromosome have coded sufficient amounts of their specific enzymes then some third G codes the enzyme giving rise to the non-dominant trait, otherwise the dominate trait appears. Second situation is the one in which traits are not yes/no properties but have discrete spectrum like red, white and pink. In this case there are two genes G_1 and G_2 coding red and white directly. Various combinations of color would correspond to three combinations G_1G_1 (red), G_2G_2 (white) and G_1G_2, G_2G_1 (pink).

The notion of many-sheeted DNA implies that gene submodules should correspond to body parts. This raises several interesting questions about what the bodily correlates of the "body part =subprogram calls second body part=subprogram". Is there some kind of communication occurring between body parts also? Perhaps chemical communication based on the same enzymes that regulate gene transcription? Gene modules call gene modules corresponding to smaller sized body parts: is this true also for the communication between body parts? Or does signal transfer occur in dual manner from small body parts to larger ones?

If this kind of correspondence exists, say, at hormonal level, one could directly deduce information about the structure of genetic program from the topology of the hormonal communications. For instance, genome should have central unit analogous to brain receiving information from controlling the activities of the rest of the genome. An obvious candidate for the brain of chromosome is centromere. Centromere seems to be analogous to brain in the sense that lot of repetitive DNA presumably controlling gene expression is situated near the centromere.

What about cognitive fermion pairs as representation of memetic codons?

According to the original speculations, memetic code could be represented as temporal sequences of what I called cognitive neutrino pairs with neutrino and antineutrino assigned with the opposite throats of a wormhole contact carrying Z^0 magnetic flux and assumed to be associated with cell membrane. The possibility of these sequences was argued to be allowed by the failure of the strict determinism for Kähler action. This idea might indeed make sense if cell membrane is near vacuum extremal and corresponds to a scaled variant of weak interaction physics with the weak length scale being of order cell size scale so that classical Z^0 and W fields become important (both non-standard value of $\hbar_{eff}$ and different p-adic length scale for weak bosons could give rise to scaled variants of weak interaction physics). From the point of view of standard model the idea is of course complete non-sense. The basic support for the idea about scaled variants of weak interaction physics is that it could understand the mysterious large parity breaking in living matter in this manner.

The weak point of the original idea was the assumption that the negative sign for neutrino energy is due to its interaction with classical Z^0 electric field. The idea however generalizes considerably in the framework of zero energy ontology (ZEO) inspired much later by the non-determinism of Kähler action. Causal diamond (CD) becomes the basic geometric objects and is identified as correlate for a spotlight of consciousness. The simplest zero energy states assignable to CD would correspond to fermions with opposite quantum numbers localized at the two light-like boundaries of CD (this only approximately since second boundary correspond to a superposition of states appearing as final states for the possible decays of the fermion).

The positive energy fermion has fermion number, weak isospin, and spin and allows representations of binary digit. In particular, nucleotides A, T, C, G could be represented in terms of these quantum numbers. The representation of in terms of u, d and their antiquarks is only one representations. The idea is that one can construct negentropically entangled temporal sequences of this kind of CDs having interpretation as bit sequences. This could give rise to a representation of also memetic codons as sequences of 126 binary digits represented in terms of fermions or as sequences of 21 triplets of binary 2-digits representable as zero energy states representing dark DNA codons.

Could DNA level contribute to our consciousness

The fermionic Boolean algebra defined by fermionic Fock state basis is a natural candidate for a quantum physical correlate for Boolean thoughts [K44]. In zero energy ontology (ZEO) the pairs of positive and negative energy fermion states with opposite net fermion numbers are in turn natural candidates for pairs of Boolean statements consistent with each other: basically they could code for the "laws of physics".

This suggest that some part of neuronal genome, whose dynamics is slow as compared to neural dynamics but consistent with the slow dynamics of the belief system as required, stores information, not only about the physical structure of organism, but also about our belief structures, intentions and long term goals. These beliefs become conscious when gene is activated, perhaps by neural activity: neural transmission is indeed known to induce effects at gene level. The statements represented by genes would correspond directly to our conscious beliefs at various levels of the space-time sheet hierarchy! Perhaps the memetic codewords consisting of 21 DNA codons (also dark DNA codons) could have interpretation as bit sequences representing integers in the range $(1, 2^{126})$ and genuine Boolean thought resides basically at the genome level.

This mechanism becomes possible only at p-adic length scales longer than neuron size scale. Therefore the emergence of genes with a total length larger than the p-adic length scale $L(169) \simeq 5$ μm should correspond to the emergence of the eukaryotes, introns and Boolean consciousness. Thus only some large enough bacteria (at least Fischerella) can have cognitive abilities. The absence of mitochondrial introns is probably due to the short length of the mitochondrial genes. The mitochondrial DNA of fungi is known to contain introns and the reason is perhaps that the length of DNA is longer than the critical length. Obviously, the proposed scenario implies a relationship between DNA level and logical thinking and partial reduction of language structures to DNA level.

In this picture genome is a collection of genes which can be regarded as Boolean algebras $B(N)$ defined by N independent binary digits. Prokaryotes would represent only $B(1)$ algebra and only single statement would be associated with gene: the only possible conscious experience associated with gene statement would be experience about the truthness of the corresponding statements. Higher level Boolean mind realized as Boolean algebras $B(N)$, $N > 1$ are present only in eukaryotes since only their DNA can have Z^0 wormhole contacts to space-times sheets $k \geq 169$. Also the genes associated with cell organelles corresponds almost as a rule to the smallest possible Boolean algebra.

9.4.3 DNA As A Topological Quantum Computer

For years ago I developed a model of topological quantum computation (TQC) combining TGD based view about space-time with basic ideas about topological quantum computation and ended up with the proposal that DNA might act as a topological quantum computer. One can imagine several ways in which DNA or RNA could act as a topological quantum computer and it good to try to state clearly what one wants.

1. Natural requirements are that the topological quantum computer programs can be naturally combined to larger programs and evolution means this kind of process; that the programs have a natural modular structure inherited from the previous stages of evolution; and that the computation is not restricted inside single nucleus.

2. DNA and/or RNA defines the hardware of topological computation and at least for more advanced topological quantum computers this hardware should be static so that only programs would be dynamical. This leaves only DNA in consideration and the entangled initial and quantum states at the ends of braids quantum states would be assignable to static DNA structures.

3. The program would be determined by different braidings connecting the states of DNA in time direction or in spatial direction. Since the genomes are identical in different nuclei, the strands could connect different nuclei or conjugate strands of double DNA strand. Reconnection process would allow to modify the hardware for TQC.

The recent progress in quantum TGD and TGD inspired quantum biology

After the advent of the first model for topological quantum computation in TGD Universe [K4], the mathematical and physical understanding of TGD has developed dramatically and the earlier quite speculative picture can be replaced with a framework which leads to a rather unique view about topological quantum computations by DNA.

1. Universe as a topological quantum computer

One can say that the recent formulation of quantum TGD states that the entire Universe behaves like a topological quantum computer. This notion of topological quantum computer differs however from the standard one in many respects.

1. The emergence of hierarchy of Planck constants realized as a generalization of the notion of embedding space is now a basic piece of TGD allowing an elegant formulation of quantum TGD [K110, K38]. The phases of matter with large Planck constant are interpreted as dark matter. Large values of Planck constant make possible topological quantum computations in arbitrary long time scales so that the most fundamental objection against quantum computation can be circumvented.

2. Zero energy ontology forces to unify S-matrix and density matrix to M-matrix - the product of the square root of density matrix and S-matrix- defined as time-like (or rather light-like) entanglement coefficients between positive and negative energy parts of zero energy state [K26, K25]. Connes tensor product emerging naturally from the notion of finite measurement resolution described in terms of inclusions of hyperfinite factors of type II_1 defines highly uniquely the M-matrix. M-matrix would be natural candidate for defining topological quantum computation in light-like direction. Connes tensor product makes sense also in space-like direction and would define quantum storage of functions represented as entanglement coefficients.

3. The notion of number theoretic braid [K111, K26] has become a basic element of the formulation of quantum TGD based on the requirement of number theoretical universality. As a matter fact, the notion of braid is generalized in the sense that braid strands can fuse and decay. One can make guesses about the details of the braid motion, which do not however matter since only topology is what matters. One could argue that the braid orbits must be light-like curves: the generic curve is locally space-like. The motion of braids corresponds to boundaries of string world sheets and the vanishing of induced weak fields at them gives a strong constraint on them. Note that one expects Kac-Moody type invariance deforming the light-like 3-surfaces and respecting their light-likeness but without changing the Kähler action and conserved quantities associated with preferred extrema.

   For generalized Feynman diagrams partonic light-like 3-surfaces meet at 2-dimensional vertices defined by partonic 2-surfaces [K25]. This implies that braids replicate at vertices: the interpretation is as a copying of classical information. Quantum information is not copied faithfully. The exchange of partonic 2-surfaces in turn corresponds to quantum communications. Hence quantum communication and quantum copying emerge naturally as additional elements. Space-like Connes tensor product in turn defines quantum memory storage.

4. Computation time is a fundamental restriction in both ordinary and quantum computation. Zero energy ontology makes possible communications in both directions of geometric time, which suggests the possibility of geometric time loops in topological quantum computations. Could this mean that computation time ceases to be a restriction and ordinary computations lasting for infinite amount of geometric time could be performed in a finite time interval of observer's time? This is perhaps too much to hope. The subjective time taken by the computation would be infinite if each step in the iteration corresponds to single quantum jump. If this is the case and if each quantum jump of observer corresponds to a finite increment of geometric time perceived by the observer, time loops would not allow miracles.

2. The notion of magnetic body and the generalization of the notion of genome

The evolution of ideas related to quantum biology provides also new valuable insights. In particular, the notion of magnetic body leads to a model of living system in which dark matter at magnetic flux quanta of the field body of biological system uses biological body as a motor instrument and sensory receptor [K35]. Quantum control would be naturally via the genome and sensory input would be from cell membrane containing all kinds of receptors. This would suggest that magnetic flux sheets traverse through DNA strands and cell membranes.

The quantization of magnetic flux with unit defined by Planck constant having arbitrarily large values leads naturally to the notions of super-genome and hyper-genome [K56]. Super-genome would consists of DNA strands of separate nuclei belonging to single magnetic flux sheet and these sequences of genomes would be like lines of text at the page of book. Super-genomes in turn can combine to form text lines at the pages of a bigger book, I have used the term hyper-genome. This hierarchy of genomes would give rise to a collective gene expression at the level of organs, individuals of a species, and at the collective level consisting of populations containing several species. Even biosphere could express itself coherently via all the genomes of the bio-sphere. The model of topological quantum computation performed by DNA should be consistent with this general picture.

Model for DNA based topological quantum computation

The most promising model of DNA as topological quantum computer relies on the hierarchy of genomes. The flux sheets or collections of parallel flux tubes assignable to a magnetic body would traverse the DNA strands of several nuclei so that strands would be analogous to lines of text on the page of a book.

DNA strands would define the intersections of magnetic or number theoretic braids with plane and braiding would be associated with with the magnetic field lines or flux tubes transversal to DNA. The M-matrix defining topological quantum computation would act on quantum states assignable to nucleotides.

1. The interpretation of nucleotides

The interpretation of the A, T, C, G degree of freedom is not obvious and one can consider several options.

1. The quantum numbers entangled by braids having nothing to do with (A, T, C, G) assignable to nucleotides and the braiding does not affect nucleotides.

2. The nucleotides (A, T, C, G) correspond to four different colors (a, t, c, g) for braid strands with conjugate nucleotides defining conjugate colors. The subgroup of allowed braidings would preserve the color patterns. The minimal assumption consistent with the mapping of nucleotides to quarks and antiquarks [K3] is that braid strands connect only nucleotides and conjugate nucleotides.

3. The model requires that the genomes in different nuclei are identical: otherwise it is not possible to realize braidings as symmetry transformations mapping portions of DNA to their conjugates (as noticed, this map would not occur at the chemical level). An interesting question is whether also the permutations of nucleotides of different codons are allowed or whether only codons are permuted so that they would define fundamental sub-programs.

4. One can understand why the minimum number of nucleotides in a codon is three. The point is that braid group is non-commutative only when the number of strands is larger than 2. The braidings acting as symmetries would correspond to a subgroup of ordinary braidings leaving the color pattern of braid invariant. Obviously the group is generated by some minimal number of combinations of ordinary braid generators. For instance, for two braid strands with different colors the generator is e_1^2 rather than e_1 (two exchange operations/full 2π twist). For codons one would have four different subgroups of full braid group corresponding to codons of type XXX, XYY, XXY, and XYZ. Each gene would be characterized by its own subgroup of braid group and thus by an M-matrix defining topological quantum computation.

5. It might be possible to understand the "junk DNA" character of introns. Introns are the most natural candidates for the portions of genome participating topological quantum computations. The transcription process would disturb topological quantum computation so that

introns should be chemically passive. Since the portion of "junk DNA" increases with the evolutionary level of the species evolution would indeed correspond to an increase the amount of topological quantum computations performed.

2. Two realizations of topological quantum computation and their combination

One can imagine two basic realizations of topological quantum computation like processes- or to be more precise - entanglement by braiding. In TGD framework this entanglement could be interpreted in terms of Connes tensor product.

2.1 Space-like entanglement

The first realization would rely space-like braids. Braid strands would connect identical lines of text at the page of book defined by sequences of genomes of different nuclei. Inside nucleus the strands would connect DNA and its conjugate. The braiding operation would take place between lines.

In this case it would be perhaps more appropriate to speak about quantum memory storage of a function realized as entanglement. These functions could represent various rules about the behavior of and survival in the physical world. For this option A, T, C, G cannot correspond to entangled quantum numbers and the interpretation as braid colors is natural. Braiding cannot correspond to a physical braiding of nucleotides so that (A, T, C, G) could correspond to braid color (strands would connect only identical nucleotides).

Strands would not connect strand and its conjugate like hydrogen bonds do but would be like long flux lines of dipole field starting from nucleotide and ending to its conjugate so that braiding would emerge naturally. Color magnetic flux tube structures of almost atom size appear in the TGD based model of nucleus and have light quarks and anti-quarks at their ends [L2] , [L2]. This could be the case also now since quarks and anti-quarks appear also in the model of high T_c superconductivity which should be present also in living matter [K35].

2.2. Light-like entanglement

Second realization would rely on light-like braids at the boundaries of light-like 3-surfaces connecting 2-surfaces assignable to single genome at different moments of time. Braiding would be dynamical and dance metaphor would apply. The light-like surface could intersect genomes only at initial and final moments and strands would connect only identical nucleotides. Light-likeness in the induced metric of course allows the partonic 3-surface to look static at the level of embedding space.

What number theoretic braid is, is far from clear. I have proposed the identification of fundamental number theoretic braids in terms of the minima of the Higgs like field associated with the Kähler-Dirac operator would be very natural in this case. An alternative definition of braids would as boundaries of string world sheets at which spinor modes are located. This definition is not however completely unique.

Genes would define only the hardware unless they code for the magnetic body of DNA too, which looks implausible. The presence of quantum memory and quantum programs would mean a breakdown of genetic determinism since the braidings representing memories and programs would develop quantum jump by quantum jump and distinguish between individuals with the same genome. Also the personal development of individual would take place at this level. It would be these programs (that is magnetic bodies) which would differentiate between us and our cousins with almost identical genome.

2.3 Combination of the two realizations

These two variants of TQC accompany each other automatically if DNA nucleotides are connected to the lipids by magnetic flux tubes [K3]. In this case the 2-D flow of lipids induced by the self organization pattern of the metabolically induced flow of cellular water would induce the TQC as dance and this in turn would would generate braiding of flux tubes connecting lipids to the nucleotides. Presumably a gel-sol transition of cytoplasm accompanies TQC in this kind of situation.

Biological evolution as an evolution of topological quantum computation

This framework allows to understand biological evolution as an evolution of topological quantum computation like processes in which already existing programs become building blocks of more complex programs.

1. The transition from RNA era to DNA era involving also the emergence of cell membrane bounded structures would mean the emergence of the topological quantum computation using a static hardware.

2. For mono-cellulars double DNA strands define space-like topological quantum computations involving only single step if the braids connect the nucleotides of the two DNA strands: obviously a reason why for double DNA strands.

3. For multicellular organisms more complex space-like topological quantum computations would emerge and could code rules about environment and multicellular survival in it. At this step also introns specialized to topological quantum computation would emerge.

4. A further evolution as a generation of super-genomes in turn forming hyper-genomes and even higher structures would have a concrete counterpart as the organization of braids of lower level to form braids at higher level so that topological quantum computations would become increasingly complex and program module structure would emerge very naturally.

9.5 Ideas About Concrete Realization Of Genetic Programs

In this section some ideas about concrete realization of genetic programs are discussed. The ideas derive from the first years of TGD inspired quantum biology and it would be interesting to see how the systematic application of recent understanding of TGD could enrichen the picture.

9.5.1 How Gene Expression Is Regulated?

In case of prokaryotes the regulation of transcription is quite satisfactorily understood. The problem is to understand how transcription is regulated in case of the eukaryotes and here the notion of many-sheeted DNA could be crucial.

Operon theory for the regulation of gene expression in prokaryotes

Jacob, Monod and Pardee [I76] suggested operon theory for the regulation of the transcription of genes responsible for lactose production in E. coli. The presence of lactose induces E. coli to produce 3 enzymes needed in the production of lactose. The enzymes correspond to three structure genes x, y, z of lactose. The mechanism is following.

1. So called i gene regulates the production of the building block proteins of the repressor protein which self-assembles as tetramer of the repressor protein.

2. Repressor protein binds to a specific site next to the promotor and hinders the binding of the RNA polymerase so that transcription becomes impossible.

3. Inductor, in the present case lactose, binds to the repressor protein and hence hinders the formation of the repressor tetrameres so that transcription becomes possible.

4. The transcript contains not only the gene but also the entire operon so that several genes are translated simultaneously.

How eukaryotes differ from prokaryotes?

Operon theory does not generalize as such to eukaryotes. Although the notion of the promoter generalizes, there is no clear-cut evidence for operons [I76]. Rather, silencers and enhancers could take the role of the inducers and repressors in the eukaryotic gene expression. The action of a silencer/enhancer is not sensitive to its precise location or orientation and the distance from

promoter can be more than thousand nucleotide pairs. TGD based explanation is based on the notions of many-sheeted DNA and protein. Silencers and enhancers mediate the interaction of the atomic space-time sheet of DNA with the classical fields of some larger space-time sheet. This interaction makes possible top-bottom type control analogous to the control of slave by master in Haken's theory of self-organization. Both classical em and Z^0 fields can control the gene expression in this manner. In eukaryotes classical Z^0 fields could have especially important role. Classical Z^0 fields are believed to be crucial for the model of cognition and this suggests that "mind-matter" interaction could at least partially relay on classical Z^0 fields and enhancers/silencers. Silencers and enhancers could make also possible Josephson junctions between gene space-time sheet and some larger space-time sheet and thus realize "biofeedback".

Second difference is related to introns. It is known that introns and exons can change their roles and it is known that there are several pathways for splicing leading to different proteins, isoforms. The replacement of single-valued gene→ polypeptide map with many-valued map obviously increases the information content of gene. The interpretation of introns and exons as two interspersed computer codes with intron lines of code separated from exons by "comment signs" marking each nucleotide of intron is attractive model for the situation. Dropping of some comment signs changes the result of the splicing process. Comment sign distribution could be dynamical and tissue specific so that one could say that genome is not invariant of species but only of a particular tissue type. This obviously reduces the genetic determinism and gives organism better abilities to survive. In human genome 1 percent of gene corresponds to exons in the "normal" state (in whatever manner that state is defined). The number of various combinations of exon and intron combinations is 2^N where N denotes the numbers of basic components of gene (perhaps coding proteins having no decomposition to modular proteins). The number of combinations increases exponentially with N and provides huge flexibility.

The interpretation of various exon-intron decompositions as statements of Boolean algebra of statements about N basic statements suggests strongly itself. In particular, exonic and intronic proteins for same intron-exon decomposition would naturally correspond to a statement and its negation. Thus one could regard eukaryotes as representing higher levels in the hierarchy of abstractions in which prokaryotes represent the lowest level. Eukaryotic genome would be a collection of genes identifiable as Boolean algebras and the running of the genetic program would mean that at given moment some statement in some of these Boolean algebras is experienced to be true. This kind of identification would mean effectively understanding of the logical meaning of the genetic code. The dominance of particular exon-intron decomposition over its complement would simply mean that this Boolean statement is true while its complement is not true. This suggests the possibility that only those 2^{N-1} exon-intron configuration which represent statements consistent with a given atomic statement are usually realized (atomic statement corresponds to a one-element subset in the set theoretic representation of Boolean algebra).

The fact that introns and exons are set theoretical complements of each other raises the possibility that the proteins coded by introns and exons have opposite effects as transcription factors. For instance, exons could code enhancer and introns could code silencer. This implies that same gene can act as both enhancer and silencer. The only thing needed is that the roles of introns and exons are changed. When this occurs, the production of intron-RNA complexes begins and the production of the composite protein coded by introns acting as exons stops. When the production of silencer protein coded by introns ceases, the silencer proteins associated with the operator sites gradually decay and gene expression also enhanced by enhancer proteins can start. Thus the activation of the gene module activates automatically the gene modules which it calls and genetic program runs.

This would suggests rather general mechanism of gene expression.

1. There exists 2^{N-1} exon-intron decomposition plus their complements. Depending on the state of gene with given exon-intron decomposition, exons or introns are translated to protein. Both introns and exons represent statements. The modular decomposition of protein to subproteins often represented by the decomposition to exons corresponds to the decomposition of the statement E to $E = E_1\&E_2...\&E_n$. Same holds true for I: $I = I_1\&I_2...\&I_n$.

2. The proteins coded usually by exons activate some genes and these proteins appear as prerequisites of type

$$IF\ [E_1\ OR\ E_2 \cdots\ OR\ E_n]\ THEN \cdots\ .$$

The presence of all activators is not necessary.

3. Introns correspond to repressors quite generally. The proteins coded by introns in the "abnormal" state of the gene correspond to prerequisites of type

$$\cdots IF\,[NOT(I_1)\&NOT(I_2)...\&NOT(I_n)]\ THEN \cdots\ .$$

This means that the absence of all repressors from operator site is necessary. The general form of gene statement is

$$IF\ [E_1\ OR\ E_2 \cdots\ OR\ E_n]\,\&IF\,[NOT(I_1)\&NOT(I_2)...\&NOT(I_n)]\ THEN \cdots\ .$$

Various E_k: s and I_k: s represent proteins in turn having modular decomposition to a product of more primitive statements.

The role of the hierarchy of Josephson currents

The control– and coordination hierarchy formed by super conductors represented by space-time sheets coupled to each other by join along boundaries bonds suggests new quantum level control mechanisms for genetic expression. Josephson currents at resonant frequencies corresponding to some magnetic transition of gene or its substructure could "wake-up" the gene self and initiate the self-organization process leading to the gene activity. Silencers and enhancers could correspond to proteins which have join along boundaries bonds/flux tube contacts to larger space-time sheets serving as masters. This would explain why neither the exact position nor orientation of the silencer or enhancer is not important for their functioning.

Various genesandassociated control structures have mutual Josephson junctions controlling gene expression. This would mean the presence of extremely weak longitudinal electromagnetic fields (the potential differences over Josephson junctions would be in 10^{-14} eV range). The control mechanisms behind morphogenesis are poorly understood and phase gradients along chromosomes and along the growing organism could be involved with the control of morphogenesis. The fact that the rate of the translation process is about 20 amino-acids per seconds is in accordance with the idea that this process is controlled by a Josephson current associated with some ion having this frequency.

9.5.2 Model For The Physical Distinction Between Exons And Introns

Introns seem to begin with nucleotide pair CT and end with pair TC: the assumption that this is the sole signature of the beginning of intron is however not consistent with the observation about the change of the roles of intron and exons. Furthermore, this criterion is obviously not sufficient for telling where intron begins and ends since also ordinary genes can contain similar section.

There are several constraints on the marking telling whether a given nucleotide is exon or intron.

1. The splicing mechanism or DNA telling which portions of it are transcribed to mRNA should rely on the marking mechanism. This requires that the enzymes responsible for the splicing are able to distinguish between introns and exons.

2. Introns can start and end in the middle of DNA triplet. This suggests that the marking is assigned with each nucleotide separately rather than each codon.

3. Both intronic and exon portions of DNA are transcribed to mRNA and splicing of the intronic portions of mRNA occurs only after that. Therefore the total length of the exon portions of DNA corresponding to a given gene must correspond to integer multiple of codons and there must exist some mechanism forcing this. The length of the intronic portions seems to be free.

4. The transformations of exons and introns to each other are known to occur. Tere must exist a physical mechanism changing the marking.

Could magnetic flux tubes serving as braid strands distinguish between introns and exons?

A priori one can imagine an endless number of possibilities for the physical realization of the binary digit distinguishing between exon and intron nucleotide. The vision about DNA as topological quantum computer with flux tubes connecting introns to the lipids of nuclear and cell membranes (not necessarily those of same nucleus or cell) acting as braid strands would realize this distinction naturally: the introduction of the connecting flux tube would transform exon an intron. Reconnection of pairs of flux tubes between DNA nucleotides or codons and lipids would allow to effectively eliminate the braid strands and transform pair of introns to exons. The first guess would be that the presence of braid strand could make it impossible to perform transcription. This is not the case: both intronic and exon portions are transcribed to mRNA and slicing process cuts off the intronic portions of mRNA after that.

1. The original model of DNA as topological quantum computer [K3] assigns to the nucleotides A, T, C, G quarks u and d and antiquarks $\overline{u}$ and $\overline{d}$. This model has intriguing properties: for instance, matter-antimatter asymmetry would have representation at the level of genetic code. This representation is consistent with the fact that the intron-exon boundary can occur in the middle of the codon.

2. An alternative highly attractive option is inspired by the notion of dark DNA [L2, K47]. The model for dark proton predicts under rather general assumptions that the states of dark proton correspond to those of DNA, RNA, tRNA, amino-acids. The model also predicts vertebrate genetic code correctly. This leads to quite far reaching vision about the role of dark nuclear physics in biology and evolution. Dark proton consists of three quarks (uud) but since the quarks are entangled one cannot assign a decomposition to counterparts of nucleotides to the dark proton.

   The observation of Hu and Wu [J25] related to the magnetic properties of cell membrane inspire the proposal that the dark proton sequences representing DNA sequences are associated with the lipid layers of the cell membrane as analog of double DNA strand [K22]. Unfortunately this identification is not consistent with the finding that exon-intron distinction is defined at the level of nucleotides rather than codons.

Can one save the latter option, and could both options be mutually consistent? In many-sheeted space-time nucleotides and codons naturally correspond to different space-time sheets being analogous to quark and hadron space-time sheets. Hence the two models could be consistent.

What distinguishes between the lipids to which nucleotides and codons connect? Do codons connect to sequences of three lipids such that each of them connects to nucleotide of the codon? Or do nucleotides connect to the lipids of the nuclear membrane and codons to the lipids of the cell membrane. The latter option looks rather elegant and would also provide an answer to the question "Nuclear or cell membranes or both?". Note that one can also consider memetic codons realised as sequences of 21 DNA codons connected by flux tubes to sequences of 21 dark protons as even higher level structures. This kind of flux tubes could connect DNAs of nuclei of different cells.

What forces exons and introns to contain integer multiple of 3 nucleotides?

What could be the physical mechanism forcing the total length of the exonic and intronic sections to be integer multiples of codons?

1. A possible mechanism is based on the existence of a phase gradient along the DNA sequence such that the increments of the phase Φ for exons of a given gene would sum up to an integer multiple of $\Delta\Phi_{tot} = n2\pi$. For intronic portions the phase gradient could vanish- The phase gradient could correspond to the phase difference associated with the weakly coupled super

conductors formed by the two DNA strands or the phases of the supra currents flowing in DNA strands.

Phase gradient is naturally accompanied by an electric field and electric fields parallel to linear molecules appear frequently in biology: DC currents of Beck indeed require the existence of electric voltage along linear structure in question [L18]. Thus flux tubes would carry both electric and magnetic fields for exon portions and could be purely magnetic for intron portions.

This mechanism allows a variant for which only exon portions are accompanied by magnetic flux tubes carrying also electric field.

2. The phase gradient must be transferred also to mRNA and splicing mechanism must detect its presence in order to cut away the portions of mRNA for which the phase gradient vanishes. This would mean that also flux tubes marking gene portions must be transcribed.

3. An attractive possibility is that the phase gradient is related with the helical structure of DNA double helix: the minimum number of DNA triplets giving rise to a multiple of 2π rotation of the helix is 10 and corresponds to the p-adic length scale $L(151)$ defining the thickness of the cell membrane. The helix can be characterized by the tangent vector of helix having axial and azimutal components:

$$K = (1, \frac{d\phi}{dz}) = (1, 10 \times 2\pi) \times \frac{1}{L(151)} \quad .$$

The phase gradient would be naturally a multiple of this vector

$$\frac{d\Phi}{dz} = nK \quad .$$

For $n = 10$ the increase of Φ would be 2π per single DNA triplet. For $n = 1$, $n = 2$, $n = 5$ and $n = 10$ the allowed lengths would come in multiples of periods 10, 5 and 2 and 1 DNA triplets respectively. Note that 5 triplets corresponds to the p-adic length scale $L(149)$ associated with the lipid layer of the cell membrane. The presence of this gradient would naturally define the splitting of the nucleotide sequence to DNA triplets and might be important in the dynamics of DNA translation and transcription.

Are the properties of the introns consistent with the proposed model?

The proposed interpretation of introns is consistent with the basic facts about them.

1. It has been found that the precise positions of introns in gene do not seem to affect the gene expression. Introns can start in the middle of protein building block or even in the middle of codeword.

The content of intron DNA does not correlate with the content of protein DNA. This is just what the model predicts. Introns are known to wander around genome and between cells. One could interpret their presence as some kind of experimentation with small modifications of the quantum software. The addition of intronic section to the gene does not in general have any dramatic consequences as far as gene expression is considered. If DNA acts as topological quantum computer, the addition of intronic portion would be like addition of software to a computer: a topological quantum computer program defined by the braiding assignable to the intronic section of DNA.

An interesting question is how much intron distribution affects genetic during the evolution of individual and how large the differences between members of species are.

2. In the proposed picture the evolutionary step leading from prokaryotes to eukaryotes was the emergence of the introns and gene programs having also intronic mRNA as output. This was perhaps necessitated by the emergence of the cell nucleus since introns were needed as input by the genetic program transferring mRNA out of nucleus. The emergence of the cell nucleus as $L(163)$ structure could in principle have occurred already for a cell of size $L(k) = 167$.

It seems that in cells of animals the size of the nucleus corresponds to $L(163)$ or perhaps even $L(167)$. Cell nucleus is however not all that is needed for the emergence of introns: the model requires the presence of $k = 169$ level in the hierarchy.

3. What is beautiful is that homing [I103] and retrohoming [I81] phenomena can be regarded as modification of the genetic program in a way which is automatically internally consistent! The addition of intron does not spoil the running of the genetic program. One can quite well consider the possibility that organisms are continually experimenting with various modifications of genetic program. It might even be that homing and retrohoming phenomena make possible the evolution of the genetic program during the lifetime of individual.

If the entire mRNA corresponds to intronic portion of DNA, it remains inside nucleus. These DNA sequences might appear in cells and the mRNA in question could be seen as a remnant of RNA era. Part of silent DNA could correspond to purely intronic genes.

1. Histones form the basic protein building block of chromosomes. Histone genes are known to contain no introns. The interpretation is that the gene coding histone is in exon state permanently. If histone genes contained intron parts, histones could act as repressor genes and regulate gene activity. Since histones appear as building block proteins of nucleosomes of chromosomes, this would mean that the programs of operating system would depend on the quantum software defined by introns: obviously a highly undesired situation. Also interferons are known to have no introns. The explanation might be similar. This could explain also why the DNA of mitochondria contains no introns.

2. It is known that the pseudogenes obtained by splitting the introns are not active. For instance, the noncoding RNA and mRNA coded by gene is not translated and is left inside the nucleus. The simplest interpretation is that intronic portions define topological quantum computer programs need to carry out mRNA and transfer it from the nucleus. This interpretation would suggest that the TQC: s defined by the flux tubes connecting nucleotides to nuclear membrane are responsible for this. The TQC: s responsible for transferring molecules through the cell membrane would involves braids connecting DNA and cell membrane. The hierarchy could continue to multicellular level. In this picture the braid strands would also serve as molecular highways along which the transfer would take place.

9.5.3 The Phenomenon Of Superimposed Genes

Before the discovery of the structure of the genome of $\phi X174$, it was thought that the Central Dogma is absolute truth. It has however turned out that genes within genes and even overlapping genes are possible [I76]. Bacteriophage $\phi X174$, which is virus with single stranded circular DNA, contains two genes, denoted by A and D, containing genes B and E within them. A gene contains also gene A^* which starts in the middle of A and ends in the same codeword. Also the translation of a gene overlapping with A and gene C next to it have been observed in G4 bacteriophage having genome very similar to that of $\phi X174$.

To understand how the translation of mRNA can give rise to genes inside genes, one is forced to introduce the notion of reading frame shift. This concept is somewhat ad hoc since it requires that the translation of a gene within gene does not obey the usual rules since reading is stopped without stopping sign.

The geometric realization of the subprogram structure might make possible to understand gene superimposition.

1. Geometrically gene would be a linear model for its expression domain obtained by thinning it to DNA thread. Two subsequent genes G_1 and G_2 are like two subsequent body parts. If gene superposition occurs, there is third body part having overlap with both and "glued" to both: kind of joint connecting two body parts.

2. In computer analogy these "body parts" correspond would represent subprograms. Transcription generates protein which refers to some other program module realized as "body part". If the requirement that each "body part" generates program call to existing "body part", is satisfied, then gene superimposition is possible. This requirement is actually very

natural consistency condition. That our body is full of this kind of joints would suggest that gene superposition is a general phenomenon.

A concrete model is obtained in terms of many-sheeted DNA and many-sheeted versions of various RNAs. As a matter of fact, the notion of many-sheeted DNA conforms with what the picture based on the notion of magnetic body having hierarchical structure with flux quanta inside flux quanta and flux sheets traversing through sub-units of DNA sequence, suggests.

9.5.4 Possible Explanations Of The Silent DNA

Genome contains large amounts of silent DNA which is not transcribed. One can consider several explanations of silent DNA in TGD framework.

1. Each gene consists of a transcribed part and control part contained in region between gene and its precedessor. It might be that highly repetitive DNA located near the centromere corresponds actually to a control part of DNA and is therefore not transcribed. Enhancers and silencers could be in question and they could have contacts to larger space-time sheets and take care of the control in long length scale enhancing or silencing a large number of genes simultaneously.

2. Genome can be regarded as a large collection of program modules calling each other. Large programs typically contain a great number of modules not used by the average user. There is also a larger number of program modules whose output is not visible to the user. Silent DNA could correspond to program modules of this kind. The counterpart of unused program modules are genes which are permanently repressed. This kind of permanent repression certainly occurs during differentiation and most of DNA in given part of organism is this kind of DNA.

3. Silent DNA could also correspond to purely intronic genes which correspond to dead ends of the genetic program and are decoupled from genetic program by selection.

4. The most radical possibility is that silent DNA corresponds to genes which are expressed non-chemically and corresponding control regions affected by non-chemical transcription factors. A possible test for the existence of non-chemical gene expression is to modify the silent part of, say, neural genome and find whether and how this affects the behavior of the organism.

5. The vision about DNA as topological quantum computer [K3] had not emerged as I wrote the above list for the first time. This vision would identify silent DNA as part of software whereas genes in this framework could be seen as hardware. What makes this option especially attractive is that the detailed nucleotide composition of the DNA strand is not crucial for the functioning of the TQC program: what matters mostly is the braiding of the flux tubes connecting nucleotides/codons to lipids. The nucleotide decomposition brings only effective coloring of the braid strands which causes additional delicate effects. Therefore the braidings associated with the repetitive structures suggesting strongly the interpretation as "junk" can quite well serve as TQC programs.

9.5.5 About Genetic Evolution

The proposed general model of genetic program provides nontrivial insights to evolution of genome.

ORP and the structure of the genetic program

An interesting question is whether "ontogeny recapitulates phylogeny" principle in its original form (to be distinguished by its TGD based analog applying much more generally) could give nontrivial constraints on the structure of the genetic program.

1. One could argue that the structure of the genetic program must reflect its evolution. In the beginning of development only the lowest level genes are activated and in turn activate more evolved genes which in turn $\cdots$. The gradual emergence of new hierarchy levels would

have interpretation as emergence of new abstraction levels: statements about statements about... are formed. These levels correspond to emergence of higher level selves having more abstracted experiences about the state of organism or its organs. Geometrically the new levels would correspond to the appearance of new space-time sheets in the hierarchy of space-time sheets assignable to the magnetic body of the genome.

2. One can also defend quite different point of view. The evolution starts from simple main program corresponding to, say the length scale of a fertilized egg. Gradually subprograms corresponding to the emergence of smaller length scale structures are activated. In growth stage simple replication of the basic structure together with the activation of the lower level programs giving rise to differentiation occurs. This leads to join along boundaries/flux tube condensates of the fundamental expression domains having some finite size determined by the metabolic resources available and by self-organization. In fact, the general structure of embryogenesis supports this view whereas evolution of more complex organisms supports the first option.

3. Option 2) suggests that genetic program modules call only modules associated with shorter length scales so that higher levels cannot be activated by program call. If this is the case new levels should emerge when some space-time sheet associated with DNA expands in phase transition like manner and fuses with corresponding space-time sheets associated with neighboring cells. These phase transitions would represent the self-organization aspect of development.

4. Cell differentiation could be understood as resulting from the branching of genetic program in position dependent manner caused by diffusion gradients of transcription factors. For instance, these transcription factors would correspond to hormones which bind to receptors to form a complex binding to gene.

Homeostasis, loops, tautologies

If P then P is the simplest loop one can imagine and corresponds to a gene coding protein activating the gene itself. Biologically this represents endless cancer like growth limited only by lifetime of protein and resources and hence possible breakdown of the system! More complicated statement structures of this type represent n-fold tautologies: *If* P_1 *then* P_2 , *If* P_2 *then* P_3 , ..., *If* P_n *then* P_1 . These systems are also self-amplifying and correspond to a cyclic reaction in which genes code enzymes activating other genes in the cycle.

This kind of cycles might be involved with the very early evolution of life. For instance, DNA-RNA-protein trinity might have developed from a situation in which RNA coded protein which catalyzed both the reverse transcription of RNA to DNA and transcription of DNA to RNA. Thus simplest life form would have represented tautology *If P then P* ! Reverse transcription such that the reverse transcriptase also catalyzes transcription is indeed known to occur. Certain plant viruses contain inverse transcriptase synthetizing in infected cell DNA from its RNA and then DNA complementary to this. This double strand joins to the genome of the host cell and duplicates itself.

More complicated cycles involving several equivalent statements would have evolved gradually (note the parallel with the generation of mathematical theorems stating equivalence of statements!). Bacteria replicate endlessly and might perhaps be regarded as example of life form which corresponds to n-fold tautology.

The role of chromosomes

An interesting question is whether the organization of the genome to chromosomes could have some deeper organizational meaning. The fact that chromosome fusions and splittings are possible, suggests that chromosomes as a whole cannot have direct identification in terms of any body structure. Indeed, the realization of genetic program in terms of protein concentrations representing inputs and outputs of genes interpreted as subprograms is very flexible as far as the location of gene subprograms is considered. Only genes which form larger program structures should form geometrically connected units and the relative locations of these units could be rather free. As already found, genes seem indeed form clear geometrical subunits.

Animal	Man	Chimpanzee	Cow	Dog	Cat
N_c	23	24	30	39	19
Animal	Horse	Rat	Rabbit	Alligator	Frog
N_c	32	21	22	16	13
Animal	House fly	Fruit fly	Honeybee	Flatworm	Harpalinae
N_c	6	4	16	8	$18+x$

Table 9.3: Chromosome numbers for some species.

Chromosomes could be identified as a set of mutually interacting parallelly running genetic programs. One can of course consider the possibility that chromosomes mean the composition of body part to N_c linear structures, N_c being the number of chromosome pairs. Parallel interacting processing would bind these structures to single coherent hole. This division to N_c parts should be detectable at all levels of body organization. One can also consider the possibility is that the structure of chromosome parallels the structure of body and that centrosome corresponds in some sense to the brains of chromosome and the branches of chromosome correspond to right and left halves of the body. Genetic programs associated with different chromosomes are known to run in very precise synchrony. Many -sheeted DNA could explain this synchrony naturally as resulting from the interaction of genes with with classical em fields with space-time sheet containing the chromosomes.

Table 9.4 gives chromosome numbers for some animals. For the home fly the number of chromosome pairs is 6 whereas the number of the p-adic hierarchy levels determined by the size of the home fly is 12. For fruit fly the number of chromosome pairs is 4. Horse has 32 pairs of chromosomes and dog has 39 pairs of chromosomes whereas Homo sapiens has 23 chromosomes. The large number of chromosomes can be understand as a way to produce large number of outcomes in breeding. The number of possible combinations of chromosomes in sexual breeding is 2^{N_c}, 2^{16} more than in case of Homo Sapiens. There are indeed very many different looking dogs barking around! The number of chromosomes varies wildly. For instance, the number of chromosomes in Harpalinae is $18+x$ [I24]! The size of this insect is about one centimeter.

The natural expectation is that the size of chromosomes has gradually grown during evolution when new p-adic space-time sheets have emerged. This process could correspond to insertion of introns to the basic DNA. The possibility coming first in mind is that the value of k_G in genes of given chromosome tends to increase as a function of the distance from the second end of gene. Genetic program realized in terms of many-sheeted space-time concept does not however require this. The genes involved in the coding the structure of given body part are known to be linearly arranged according to the structure of body part itself. This is certainly consistent with TGD picture in which body parts grow from space-time sheets associated with DNA. It seems that the highest activated space-time sheets in genes must correspond to brain, in particular frontal lobes, in case of human. This would suggest that also in chromosome the largest active length scales correspond to the region around centrosome.

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

$$\begin{aligned} N(DNA) &= 2^{(k-149)/2} \times 5 \ , \\ k &\in \{149, 151, 157, 163, 167, 169, 174, 179, 181, 191, 193, ..\} \end{aligned} \tag{9.5.1}$$

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-assemly. 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 $1 - 10$ micro-meters. 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 structure 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 species, the larger the fraction of introns. For human genome the fraction of 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 micro-meters 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 space-time sheets with same p in all animals but the sizes of the join along boundaries/flux tube 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.

9.6 Ideas About Concrete Realization Of Genetic Programs

In this section some ideas about concrete realization of genetic programs are discussed. The ideas derive from the first years of TGD inspired quantum biology and it would be interesting to see how the systematic application of recent understanding of TGD could enrichen the picture.

9.6.1 How Gene Expression Is Regulated?

In case of prokaryotes the regulation of transcription is quite satisfactorily understood. The problem is to understand how transcription is regulated in case of the eukaryotes and here the notion of many-sheeted DNA could be crucial.

Operon theory for the regulation of gene expression in prokaryotes

Jacob, Monod and Pardee [I76] suggested operon theory for the regulation of the transcription of genes responsible for lactose production in E. coli. The presence of lactose induces E. coli to produce 3 enzymes needed in the production of lactose. The enzymes correspond to three structure genes x, y, z of lactose. The mechanism is following.

1. So called i gene regulates the production of the building block proteins of the repressor protein which self-assembles as tetramer of the repressor protein.

2. Repressor protein binds to a specific site next to the promotor and hinders the binding of the RNA polymerase so that transcription becomes impossible.

3. Inductor, in the present case lactose, binds to the repressor protein and hence hinders the formation of the repressor tetrameres so that transcription becomes possible.

4. The transcript contains not only the gene but also the entire operon so that several genes are translated simultaneously.

How eukaryotes differ from prokaryotes?

Operon theory does not generalize as such to eukaryotes. Although the notion of the promoter generalizes, there is no clear-cut evidence for operons [I76]. Rather, silencers and enhancers could take the role of the inducers and repressors in the eukaryotic gene expression. The action of a silencer/enhancer is not sensitive to its precise location or orientation and the distance from promoter can be more than thousand nucleotide pairs. TGD based explanation is based on the notions of many-sheeted DNA and protein. Silencers and enhancers mediate the interaction of the atomic space-time sheet of DNA with the classical fields of some larger space-time sheet. This interaction makes possible top-bottom type control analogous to the control of slave by master in Haken's theory of self-organization. Both classical em and Z^0 fields can control the gene expression in this manner. In eukaryotes classical Z^0 fields could have especially important role. Classical Z^0 fields are believed to be crucial for the model of cognition and this suggests that "mind-matter" interaction could at least partially relay on classical Z^0 fields and enhancers/silencers. Silencers and enhancers could make also possible Josephson junctions between gene space-time sheet and some larger space-time sheet and thus realize "biofeedback".

Second difference is related to introns. It is known that introns and exons can change their roles and it is known that there are several pathways for splicing leading to different proteins, isoforms. The replacement of single-valued gene→ polypeptide map with many-valued map obviously increases the information content of gene. The interpretation of introns and exons as two interspersed computer codes with intron lines of code separated from exons by "comment signs" marking each nucleotide of intron is attractive model for the situation. Dropping of some comment signs changes the result of the splicing process. Comment sign distribution could be dynamical and tissue specific so that one could say that genome is not invariant of species but only of a particular tissue type. This obviously reduces the genetic determinism and gives organism better abilities to survive. In human genome 1 percent of gene corresponds to exons in the "normal" state (in whatever manner that state is defined). The number of various combinations of exon and intron combinations is 2^N where N denotes the numbers of basic components of gene (perhaps coding proteins having no decomposition to modular proteins). The number of combinations increases exponentially with N and provides huge flexibility.

The interpretation of various exon-intron decompositions as statements of Boolean algebra of statements about N basic statements suggests strongly itself. In particular, exonic and intronic proteins for same intron-exon decomposition would naturally correspond to a statement and its negation. Thus one could regard eukaryotes as representing higher levels in the hierarchy of abstractions in which prokaryotes represent the lowest level. Eukaryotic genome would be a collection of genes identifiable as Boolean algebras and the running of the genetic program would mean that at given moment some statement in some of these Boolean algebras is experienced to be true. This kind of identification would mean effectively understanding of the logical meaning of the genetic code. The dominance of particular exon-intron decomposition over its complement would simply mean that this Boolean statement is true while its complement is not true. This suggests the possibility that only those 2^{N-1} exon-intron configuration which represent statements consistent with a given atomic statement are usually realized (atomic statement corresponds to a one-element subset in the set theoretic representation of Boolean algebra).

The fact that introns and exons are set theoretical complements of each other raises the possibility that the proteins coded by introns and exons have opposite effects as transcription factors. For instance, exons could code enhancer and introns could code silencer. This implies that same gene can act as both enhancer and silencer. The only thing needed is that the roles of introns and exons are changed. When this occurs, the production of intron-RNA complexes begins and the production of the composite protein coded by introns acting as exons stops. When the

production of silencer protein coded by introns ceases, the silencer proteins associated with the operator sites gradually decay and gene expression also enhanced by enhancer proteins can start. Thus the activation of the gene module activates automatically the gene modules which it calls and genetic program runs.

This would suggests rather general mechanism of gene expression.

1. There exists 2^{N-1} exon-intron decomposition plus their complements. Depending on the state of gene with given exon-intron decomposition, exons or introns are translated to protein. Both introns and exons represent statements. The modular decomposition of protein to subproteins often represented by the decomposition to exons corresponds to the decomposition of the statement E to $E = E_1\&E_2...\&E_n$. Same holds true for I: $I = I_1\&I_2...\&I_n$.

2. The proteins coded usually by exons activate some genes and these proteins appear as prerequisites of type

$$IF\ [E_1\ OR\ E_2 \cdots\ OR\ E_n]\ THEN \cdots\ .$$

   The presence of all activators is not necessary.

3. Introns correspond to repressors quite generally. The proteins coded by introns in the "abnormal" state of the gene correspond to prerequisites of type

$$\cdots IF\,[NOT(I_1)\&NOT(I_2)...\&NOT(I_n)]\ THEN \cdots\ .$$

   This means that the absence of all repressors from operator site is necessary. The general form of gene statement is

$$IF\ [E_1\ OR\ E_2 \cdots\ OR\ E_n]\,\&IF\,[NOT(I_1)\&NOT(I_2)...\&NOT(I_n)]\ THEN \cdots\ .$$

   Various E_k: s and I_k: s represent proteins in turn having modular decomposition to a product of more primitive statements.

The role of the hierarchy of Josephson currents

The control– and coordination hierarchy formed by super conductors represented by space-time sheets coupled to each other by join along boundaries bonds suggests new quantum level control mechanisms for genetic expression. Josephson currents at resonant frequencies corresponding to some magnetic transition of gene or its substructure could "wake-up" the gene self and initiate the self-organization process leading to the gene activity. Silencers and enhancers could correspond to proteins which have join along boundaries bonds/flux tube contacts to larger space-time sheets serving as masters. This would explain why neither the exact position nor orientation of the silencer or enhancer is not important for their functioning.

Various genesandassociated control structures have mutual Josephson junctions controlling gene expression. This would mean the presence of extremely weak longitudinal electromagnetic fields (the potential differences over Josephson junctions would be in 10^{-14} eV range). The control mechanisms behind morphogenesis are poorly understood and phase gradients along chromosomes and along the growing organism could be involved with the control of morphogenesis. The fact that the rate of the translation process is about 20 amino-acids per seconds is in accordance with the idea that this process is controlled by a Josephson current associated with some ion having this frequency.

9.6.2 Model For The Physical Distinction Between Exons And Introns

Introns seem to begin with nucleotide pair CT and end with pair TC: the assumption that this is the sole signature of the beginning of intron is however not consistent with the observation about the change of the roles of intron and exons. Furthermore, this criterion is obviously not sufficient for telling where intron begins and ends since also ordinary genes can contain similar section.

There are several constraints on the marking telling whether a given nucleotide is exon or intron.

1. The splicing mechanism or DNA telling which portions of it are transcribed to mRNA should rely on the marking mechanism. This requires that the enzymes responsible for the splicing are able to distinguish between introns and exons.

2. Introns can start and end in the middle of DNA triplet. This suggests that the marking is assigned with each nucleotide separately rather than each codon.

3. Both intronic and exon portions of DNA are transcribed to mRNA and splicing of the intronic portions of mRNA occurs only after that. Therefore the total length of the exon portions of DNA corresponding to a given gene must correspond to integer multiple of codons and there must exist some mechanism forcing this. The length of the intronic portions seems to be free.

4. The transformations of exons and introns to each other are known to occur. Tere must exist a physical mechanism changing the marking.

Could magnetic flux tubes serving as braid strands distinguish between introns and exons?

A priori one can imagine an endless number of possibilities for the physical realization of the binary digit distinguishing between exon and intron nucleotide. The vision about DNA as topological quantum computer with flux tubes connecting introns to the lipids of nuclear and cell membranes (not necessarily those of same nucleus or cell) acting as braid strands would realize this distinction naturally: the introduction of the connecting flux tube would transform exon an intron. Reconnection of pairs of flux tubes between DNA nucleotides or codons and lipids would allow to effectively eliminate the braid strands and transform pair of introns to exons. The first guess would be that the presence of braid strand could make it impossible to perform transcription. This is not the case: both intronic and exon portions are transcribed to mRNA and slicing process cuts off the intronic portions of mRNA after that.

1. The original model of DNA as topological quantum computer [K3] assigns to the nucleotides A, T, C, G quarks u and d and antiquarks $\overline{u}$ and $\overline{d}$. This model has intriguing properties: for instance, matter-antimatter asymmetry would have representation at the level of genetic code. This representation is consistent with the fact that the intron-exon boundary can occur in the middle of the codon.

2. An alternative highly attractive option is inspired by the notion of dark DNA [L2, K47]. The model for dark proton predicts under rather general assumptions that the states of dark proton correspond to those of DNA, RNA, tRNA, amino-acids. The model also predicts vertebrate genetic code correctly. This leads to quite far reaching vision about the role of dark nuclear physics in biology and evolution. Dark proton consists of three quarks (uud) but since the quarks are entangled one cannot assign a decomposition to counterparts of nucleotides to the dark proton.

   The observation of Hu and Wu [J25] related to the magnetic properties of cell membrane inspire the proposal that the dark proton sequences representing DNA sequences are associated with the lipid layers of the cell membrane as analog of double DNA strand [K22]. Unfortunately this identification is not consistent with the finding that exon-intron distinction is defined at the level of nucleotides rather than codons.

Can one save the latter option, and could both options be mutually consistent? In many-sheeted space-time nucleotides and codons naturally correspond to different space-time sheets being analogous to quark and hadron space-time sheets. Hence the two models could be consistent.

What distinguishes between the lipids to which nucleotides and codons connect? Do codons connect to sequences of three lipids such that each of them connects to nucleotide of the codon? Or do nucleotides connect to the lipids of the nuclear membrane and codons to the lipids of the cell membrane. The latter option looks rather elegant and would also provide an answer to the

question "Nuclear or cell membranes or both?". Note that one can also consider memetic codons realised as sequences of 21 DNA codons connected by flux tubes to sequences of 21 dark protons as even higher level structures. This kind of flux tubes could connect DNAs of nuclei of different cells.

What forces exons and introns to contain integer multiple of 3 nucleotides?

What could be the physical mechanism forcing the total length of the exonic and intronic sections to be integer multiples of codons?

1. A possible mechanism is based on the existence of a phase gradient along the DNA sequence such that the increments of the phase Φ for exons of a given gene would sum up to an integer multiple of $\Delta\Phi_{tot} = n2\pi$. For intronic portions the phase gradient could vanish- The phase gradient could correspond to the phase difference associated with the weakly coupled super conductors formed by the two DNA strands or the phases of the supra currents flowing in DNA strands.

   Phase gradient is naturally accompanied by an electric field and electric fields parallel to linear molecules appear frequently in biology: DC currents of Beck indeed require the existence of electric voltage along linear structure in question [L18]. Thus flux tubes would carry both electric and magnetic fields for exon portions and could be purely magnetic for intron portions.

   This mechanism allows a variant for which only exon portions are accompanied by magnetic flux tubes carrying also electric field.

2. The phase gradient must be transferred also to mRNA and splicing mechanism must detect its presence in order to cut away the portions of mRNA for which the phase gradient vanishes. This would mean that also flux tubes marking gene portions must be transcribed.

3. An attractive possibility is that the phase gradient is related with the helical structure of DNA double helix: the minimum number of DNA triplets giving rise to a multiple of 2π rotation of the helix is 10 and corresponds to the p-adic length scale $L(151)$ defining the thickness of the cell membrane. The helix can be characterized by the tangent vector of helix having axial and azimutal components:

$$K = (1, \frac{d\phi}{dz}) = (1, 10 \times 2\pi) \times \frac{1}{L(151)} \quad .$$

   The phase gradient would be naturally a multiple of this vector

$$\frac{d\Phi}{dz} = nK \quad .$$

   For $n = 10$ the increase of Φ would be 2π per single DNA triplet. For $n = 1$, $n = 2$, $n = 5$ and $n = 10$ the allowed lengths would come in multiples of periods 10, 5 and 2 and 1 DNA triplets respectively. Note that 5 triplets corresponds to the p-adic length scale $L(149)$ associated with the lipid layer of the cell membrane. The presence of this gradient would naturally define the splitting of the nucleotide sequence to DNA triplets and might be important in the dynamics of DNA translation and transcription.

Are the properties of the introns consistent with the proposed model?

The proposed interpretation of introns is consistent with the basic facts about them.

1. It has been found that the precise positions of introns in gene do not seem to affect the gene expression. Introns can start in the middle of protein building block or even in the middle of codeword.

   The content of intron DNA does not correlate with the content of protein DNA. This is just what the model predicts. Introns are known to wander around genome and between cells. One could interpret their presence as some kind of experimentation with small modifications

of the quantum software. The addition of intronic section to the gene does not in general have any dramatic consequences as far as gene expression is considered. If DNA acts as topological quantum computer, the addition of intronic portion would be like addition of software to a computer: a topological quantum computer program defined by the braiding assignable to the intronic section of DNA.

An interesting question is how much intron distribution affects genetic during the evolution of individual and how large the differences between members of species are.

2. In the proposed picture the evolutionary step leading from prokaryotes to eukaryotes was the emergence of the introns and gene programs having also intronic mRNA as output. This was perhaps necessitated by the emergence of the cell nucleus since introns were needed as input by the genetic program transferring mRNA out of nucleus. The emergence of the cell nucleus as $L(163)$ structure could in principle have occurred already for a cell of size $L(k) = 167$. It seems that in cells of animals the size of the nucleus corresponds to $L(163)$ or perhaps even $L(167)$. Cell nucleus is however not all that is needed for the emergence of introns: the model requires the presence of $k = 169$ level in the hierarchy.

3. What is beautiful is that homing [I103] and retrohoming [I81] phenomena can be regarded as modification of the genetic program in a way which is automatically internally consistent! The addition of intron does not spoil the running of the genetic program. One can quite well consider the possibility that organisms are continually experimenting with various modifications of genetic program. It might even be that homing and retrohoming phenomena make possible the evolution of the genetic program during the lifetime of individual.

If the entire mRNA corresponds to intronic portion of DNA, it remains inside nucleus. These DNA sequences might appear in cells and the mRNA in question could be seen as a remnant of RNA era. Part of silent DNA could correspond to purely intronic genes.

1. Histones form the basic protein building block of chromosomes. Histone genes are known to contain no introns. The interpretation is that the gene coding histone is in exon state permanently. If histone genes contained intron parts, histones could act as repressor genes and regulate gene activity. Since histones appear as building block proteins of nucleosomes of chromosomes, this would mean that the programs of operating system would depend on the quantum software defined by introns: obviously a highly undesired situation. Also interferons are known to have no introns. The explanation might be similar. This could explain also why the DNA of mitochondria contains no introns.

2. It is known that the pseudogenes obtained by splitting the introns are not active. For instance, the noncoding RNA and mRNA coded by gene is not translated and is left inside the nucleus. The simplest interpretation is that intronic portions define topological quantum computer programs need to carry out mRNA and transfer it from the nucleus. This interpretation would suggest that the TQC: s defined by the flux tubes connecting nucleotides to nuclear membrane are responsible for this. The TQC: s responsible for transferring molecules through the cell membrane would involves braids connecting DNA and cell membrane. The hierarchy could continue to multicellular level. In this picture the braid strands would also serve as molecular highways along which the transfer would take place.

9.6.3 The Phenomenon Of Superimposed Genes

Before the discovery of the structure of the genome of $\phi X174$, it was thought that the Central Dogma is absolute truth. It has however turned out that genes within genes and even overlapping genes are possible [I76]. Bacteriophage $\phi X174$, which is virus with single stranded circular DNA, contains two genes, denoted by A and D, containing genes B and E within them. A gene contains also gene A^* which starts in the middle of A and ends in the same codeword. Also the translation of a gene overlapping with A and gene C next to it have been observed in G4 bacteriophage having genome very similar to that of $\phi X174$.

To understand how the translation of mRNA can give rise to genes inside genes, one is forced to introduce the notion of reading frame shift. This concept is somewhat ad hoc since it requires

that the translation of a gene within gene does not obey the usual rules since reading is stopped without stopping sign.

The geometric realization of the subprogram structure might make possible to understand gene superimposition.

1. Geometrically gene would be a linear model for its expression domain obtained by thinning it to DNA thread. Two subsequent genes G_1 and G_2 are like two subsequent body parts. If gene superposition occurs, there is third body part having overlap with both and "glued" to both: kind of joint connecting two body parts.

2. In computer analogy these "body parts" correspond would represent subprograms. Transcription generates protein which refers to some other program module realized as "body part". If the requirement that each "body part" generates program call to existing "body part", is satisfied, then gene superimposition is possible. This requirement is actually very natural consistency condition. That our body is full of this kind of joints would suggest that gene superposition is a general phenomenon.

A concrete model is obtained in terms of many-sheeted DNA and many-sheeted versions of various RNAs. As a matter of fact, the notion of many-sheeted DNA conforms with what the picture based on the notion of magnetic body having hierarchical structure with flux quanta inside flux quanta and flux sheets traversing through sub-units of DNA sequence, suggests.

9.6.4 Possible Explanations Of The Silent DNA

Genome contains large amounts of silent DNA which is not transcribed. One can consider several explanations of silent DNA in TGD framework.

1. Each gene consists of a transcribed part and control part contained in region between gene and its precedessor. It might be that highly repetitive DNA located near the centromere corresponds actually to a control part of DNA and is therefore not transcribed. Enhancers and silencers could be in question and they could have contacts to larger space-time sheets and take care of the control in long length scale enhancing or silencing a large number of genes simultaneously.

2. Genome can be regarded as a large collection of program modules calling each other. Large programs typically contain a great number of modules not used by the average user. There is also a larger number of program modules whose output is not visible to the user. Silent DNA could correspond to program modules of this kind. The counterpart of unused program modules are genes which are permanently repressed. This kind of permanent repression certainly occurs during differentiation and most of DNA in given part of organism is this kind of DNA.

3. Silent DNA could also correspond to purely intronic genes which correspond to dead ends of the genetic program and are decoupled from genetic program by selection.

4. The most radical possibility is that silent DNA corresponds to genes which are expressed non-chemically and corresponding control regions affected by non-chemical transcription factors. A possible test for the existence of non-chemical gene expression is to modify the silent part of, say, neural genome and find whether and how this affects the behavior of the organism.

5. The vision about DNA as topological quantum computer [K3] had not emerged as I wrote the above list for the first time. This vision would identify silent DNA as part of software whereas genes in this framework could be seen as hardware. What makes this option especially attractive is that the detailed nucleotide composition of the DNA strand is not crucial for the functioning of the TQC program: what matters mostly is the braiding of the flux tubes connecting nucleotides/codons to lipids. The nucleotide decomposition brings only effective coloring of the braid strands which causes additional delicate effects. Therefore the braidings associated with the repetitive structures suggesting strongly the interpretation as "junk" can quite well serve as TQC programs.

9.6.5 About Genetic Evolution

The proposed general model of genetic program provides nontrivial insights to evolution of genome.

ORP and the structure of the genetic program

An interesting question is whether "ontogeny recapitulates phylogeny" principle in its original form (to be distinguished by its TGD based analog applying much more generally) could give nontrivial constraints on the structure of the genetic program.

1. One could argue that the structure of the genetic program must reflect its evolution. In the beginning of development only the lowest level genes are activated and in turn activate more evolved genes which in turn $\cdots$. The gradual emergence of new hierarchy levels would have interpretation as emergence of new abstraction levels: statements about statements about... are formed. These levels correspond to emergence of higher level selves having more abstracted experiences about the state of organism or its organs. Geometrically the new levels would correspond to the appearance of new space-time sheets in the hierarchy of space-time sheets assignable to the magnetic body of the genome.

2. One can also defend quite different point of view. The evolution starts from simple main program corresponding to, say the length scale of a fertilized egg. Gradually subprograms corresponding to the emergence of smaller length scale structures are activated. In growth stage simple replication of the basic structure together with the activation of the lower level programs giving rise to differentiation occurs. This leads to join along boundaries/flux tube condensates of the fundamental expression domains having some finite size determined by the metabolic resources available and by self-organization. In fact, the general structure of embryogenesis supports this view whereas evolution of more complex organisms supports the first option.

3. Option 2) suggests that genetic program modules call only modules associated with shorter length scales so that higher levels cannot be activated by program call. If this is the case new levels should emerge when some space-time sheet associated with DNA expands in phase transition like manner and fuses with corresponding space-time sheets associated with neighboring cells. These phase transitions would represent the self-organization aspect of development.

4. Cell differentiation could be understood as resulting from the branching of genetic program in position dependent manner caused by diffusion gradients of transcription factors. For instance, these transcription factors would correspond to hormones which bind to receptors to form a complex binding to gene.

Homeostasis, loops, tautologies

If P then P is the simplest loop one can imagine and corresponds to a gene coding protein activating the gene itself. Biologically this represents endless cancer like growth limited only by lifetime of protein and resources and hence possible breakdown of the system! More complicated statement structures of this type represent n-fold tautologies: *If* P_1 *then* P_2 , *If* P_2 *then* P_3 , ..., *If* P_n *then* P_1 . These systems are also self-amplifying and correspond to a cyclic reaction in which genes code enzymes activating other genes in the cycle.

This kind of cycles might be involved with the very early evolution of life. For instance, DNA-RNA-protein trinity might have developed from a situation in which RNA coded protein which catalyzed both the reverse transcription of RNA to DNA and transcription of DNA to RNA. Thus simplest life form would have represented tautology *If P then P* ! Reverse transcription such that the reverse transcriptase also catalyzes transcription is indeed known to occur. Certain plant viruses contain inverse transcriptase synthetizing in infected cell DNA from its RNA and then DNA complementary to this. This double strand joins to the genome of the host cell and duplicates itself.

Animal	Man	Chimpanzee	Cow	Dog	Cat
N_c	23	24	30	39	19
Animal	Horse	Rat	Rabbit	Alligator	Frog
N_c	32	21	22	16	13
Animal	House fly	Fruit fly	Honeybee	Flatworm	Harpalinae
N_c	6	4	16	8	$18+x$

Table 9.4: Chromosome numbers for some species.

More complicated cycles involving several equivalent statements would have evolved gradually (note the parallel with the generation of mathematical theorems stating equivalence of statements!). Bacteria replicate endlessly and might perhaps be regarded as example of life form which corresponds to n-fold tautology.

The role of chromosomes

An interesting question is whether the organization of the genome to chromosomes could have some deeper organizational meaning. The fact that chromosome fusions and splittings are possible, suggests that chromosomes as a whole cannot have direct identification in terms of any body structure. Indeed, the realization of genetic program in terms of protein concentrations representing inputs and outputs of genes interpreted as subprograms is very flexible as far as the location of gene subprograms is considered. Only genes which form larger program structures should form geometrically connected units and the relative locations of these units could be rather free. As already found, genes seem indeed form clear geometrical subunits.

Chromosomes could be identified as a set of mutually interacting parallelly running genetic programs. One can of course consider the possibility that chromosomes mean the composition of body part to N_c linear structures, N_c being the number of chromosome pairs. Parallel interacting processing would bind these structures to single coherent hole. This division to N_c parts should be detectable at all levels of body organization. One can also consider the possibility is that the structure of chromosome parallels the structure of body and that centrosome corresponds in some sense to the brains of chromosome and the branches of chromosome correspond to right and left halves of the body. Genetic programs associated with different chromosomes are known to run in very precise synchrony. Many -sheeted DNA could explain this synchrony naturally as resulting from the interaction of genes with with classical em fields with space-time sheet containing the chromosomes.

Table 9.4 gives chromosome numbers for some animals. For the home fly the number of chromosome pairs is 6 whereas the number of the p-adic hierarchy levels determined by the size of the home fly is 12. For fruit fly the number of chromosome pairs is 4. Horse has 32 pairs of chromosomes and dog has 39 pairs of chromosomes whereas Homo sapiens has 23 chromosomes. The large number of chromosomes can be understand as a way to produce large number of outcomes in breeding. The number of possible combinations of chromosomes in sexual breeding is 2^{N_c}, 2^{16} more than in case of Homo Sapiens. There are indeed very many different looking dogs barking around! The number of chromosomes varies wildly. For instance, the number of chromosomes in Harpalinae is $18+x$ [I24]! The size of this insect is about one centimeter.

The natural expectation is that the size of chromosomes has gradually grown during evolution when new p-adic space-time sheets have emerged. This process could correspond to insertion of introns to the basic DNA. The possibility coming first in mind is that the value of k_G in genes of given chromosome tends to increase as a function of the distance from the second end of gene. Genetic program realized in terms of many-sheeted space-time concept does not however require this. The genes involved in the coding the structure of given body part are known to be linearly arranged according to the structure of body part itself. This is certainly consistent with TGD picture in which body parts grow from space-time sheets associated with DNA. It seems that the highest activated space-time sheets in genes must correspond to brain, in particular frontal lobes,

in case of human. This would suggest that also in chromosome the largest active length scales correspond to the region around centrosome.

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

$$\begin{aligned} N(DNA) &= 2^{(k-149)/2} \times 5 \ , \\ k &\in \{149, 151, 157, 163, 167, 169, 174, 179, 181, 191, 193, ..\} \end{aligned} \tag{9.6.1}$$

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-assemly. 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 $1 - 10$ micro-meters. 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 structure 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 species, the larger the fraction of introns. For human genome the fraction of 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 micro-meters 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 space-time sheets with same p in all animals but the sizes of the join along boundaries/flux tube 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.

9.7 TGD Inspired Ideas About The Regulation Of Morphogenesis

The understanding of morphogenesis provides a challenge for the TGD inspired notion of the many-sheeted DNA. The difficult task is to separate chemistry from geometry and identify those features of morphogenesis necessitating the concept of the many-sheeted DNA. Also the role of quantum control mechanisms must be understood. In the sequel general ideas about the quantum control of morphogenesis are discussed and a very brief review about the morphogenesis in Drosophila is given to provide bird's eye of view about genetic control. Also Hox genes and TGD based model for Hox genes is discussed.

9.7.1 Biological Alarm Clocks And Morphogenesis

Gene expression is known to involve non-chemical transcription factors (enhancers silencers), whose underlying interaction mechanism is not not known. TGD suggest an extremely general mechanism of quantum control and coordination based on Josephson currents flowing between space-time sheets representing various levels of the biological self-hierarchy [K71, K70]. Josephson currents themselves act as clocks. In case that the potential difference over Josephson junction corresponds to the difference of the energies for the states of charge carriers localized inside either super conductor, Josephson current "wakes-up" "clock self" and initiates self-organization process. Therefore alarm clock is in question. Besides clocks and alarm clocks one can build pattern recognizers and novelty detectors and these circuits could serve as building bricks of complicated Boolean circuits controlling the functioning of living systems and also morphogenesis. Potential differences between gene space-time sheets and some larger space-time sheets, such as growing organs serving as the controllers of the gene expresion, would act as transcription factors in the sense that suitable input supra-current would "wake-up" gene self and activate self-organization process leading to gene expression.

Some examples are in order to show that this idea might have relevance.

1. The replication of the cell is an extremely complicated process but could be understood as quantum self-organization process leading to final state patter which only very mildly depends on the initial state. This process must be initiated by a "wake-up" 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 [I123]. The reference currents are generated, when the new cell is born. The process leading to the replication of the cell involves a reduction in the density of super conducting charge carriers in the critical region and this could initiate the replication 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 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 [A13], 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 [A13]. The catastrophe theoretic models proposed in [A13] 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 [A13]) 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 [A13]). 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.

9.7.2 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. Whether this is the case is an unanswered question yet. In any case, it is very difficult to imagine how chemical concentrations which carry purely local information, could code information about the size of the organ and how the evolution could have led to a chemical kinetics initiating gene expression for critical values of the various chemical concentrations. The notions of many-sheeted space-time and general hypothesis about bio-control and coordination based on a hierarchy of weakly coupled super conductors provides a fresh and more promising approach to this process. This hypothesis is discussed in detail in [K71, K70].

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. One mechanism causing the ringing would be a situation in which the potential difference associated with the Josephson junction becomes equal to the energy difference for states 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 the required conditions are achieved.

The correlation of gene expression with the size of the growing organ could be achieved as follows. Topological field quanta are characterized by a handful of vacuum quantum numbers associated with the dependence of the phases of the two CP_2 complex coordinates ξ^i on space-time coordinates (Appendix). In particular, two frequency type quantum numbers emerges. If the potential difference corresponds to the difference of the vacuum frequencies ω_1 associated with the coupled super conductors and if ω_1 correlates with the size of the corresponding structures, the ringing of the clock occurs when the size difference is critical. If the first super conductor corresponds to some structure with a fixed size (say gene) and second super conductor corresponds to the growing organ, this mechanism could indeed initiate new kind of gene expression when the growing organ reaches critical size.

9.7.3 Early Morphogenesis Of Drosophila

During the last years the understanding about the regulation of morphogenesis has grown dramatically [I130, I138]. For instance, in case of Drosophila (fruit fly) surprisingly detailed knowledge about the regulatory cascade occurring during embryogenesis exists. It is known that genetic program with 6 hierarchy levels is in action.

1. The so called maternal factors act before the onset of cellularization and lead to the segmentation of embryo. This cascade begins with the diffusion of transcription products of maternal-effect (coordinate-) genes from the anterior and posterior poles of the embryo during oögenesis. These genes define anterior-posterior polarization.

2. Maternal factors control the spatial pattern for the transcription of gap genes which are expressed in domains along the anterior to posterior axis of the embryo. Gap genes divide embryo to anterior, middle and posterior parts.

3. Gap genes regulate each other and the next set of genes in the hierarchy, pair-rule genes. These are expressed in 7 stripes of cells corresponding to every other segment.

4. At the next level of hierarchy are segment polarity genes, many of which are expressed in 14 segmentally repeated stripes. Segment polarity genes include also proteins other than transcription factors (i.e. secreted signalling molecules, receptors, kinases, etc.) and they mediate interactions between cells.

5. During cellular phase (blastula) Hox genes controlling the formation of various body parts are expressed. The lowest level of the hierarchy is represented by tissue specific genes.

The expression domains of these genes are indeed two-dimensional slices in accordance with the idea that genes can be regarded as obtained by compressing the expression domain of gene to DNA thread. This principle might be realized quite generally in the sense that the expression domains of all genes expressed inside particular body part are also slices formed as join along boundaries/flux tube condensates of fundamental expression domains whose size corresponds to some p-adic length scale.

9.7.4 Hox Genes

The discovery of the universality of so called hox (homeo box) genes has been one of the great discoveries in genetics during last few years years [I130, I138]. Surprisingly, animal species with widely different morphologies (hydra, flies, leeches, mouses and humans) seem to obey very similar body plan coded by Hox genes. Hox genes contain highly conserved nucleotide sequence called homeobox coding protein consisting of 61 amino-acids (which corresponds to DNA length of about 61 nanometers which is slightly below $L(157)$). Hox genes are also known as "selector" genes because their expression within a region of the embryo causes its cells to select a particular route of morphogenetic development determined by detailed nucleotide content of Hox gene. Hox genes function by coding what are called transcription factor proteins: these proteins bind to and activate all downstream genes necessary for the production of, say leg. Hence Hox gene for leg functions like a main program for the development of leg. Obviously, Hox genes provide a possibility to test and develop TGD based ideas about the coding and decoding of the morphology in terms of the many-sheeted DNA.

9.7.5 Evolution Of Hox Genes

The conserved nature of the homeobox sequence indicates that all Hox genes are homologous, having arisen by divergence from a common ancestral gene. Note however that the control parts of genetic program (promoter and operator regions at which various activating and repressing proteins bind) involved with Hox genes seem to vary widely. Second basic feature of Hox genes is their clustering. The development of this clustering has been studied and it has been found that all animals species must have inherited their Hox genes from a common ancestor.

1. Already plants possess single homeobox unit in their Hox gene. Doubling of the hox gene meant the emergence of a primitive head-body structure and thus of primitive animals (hydra, which are freshwater polypes, represent one studied example). Next step was doubling of this gene pair, which lead to the formation of nematode worms. The further doublings lead gradually to more complicated animals. For instance, beetle possesses 8 Hox genes, amphioxus, which is almost vertebrate, has 12 Hox genes.

2. The next step in the evolution was the doubling of the entire chromosome containing Hox cluster. The next doubling led to vertebrates with four Hox clusters located in four chromosomes. Each cluster contains a subset of 13 nonhomologous Hox genes. These clusters are labelled as Hox-A, Hox-B, Hox-C, Hox-D. n: th gene in, say cluster A, is denoted by Hox-A-n, $n = 1, .., 13$. The homologous Hox genes in various chromosomes, Hox-A-n, ..., Hox-D-n, whose number is never larger than four, form 13 groups called prologues. The maximum number of Hox genes is 52 but some of genes are missing. Each vertebrate has its own Hox-bode telling which Hox genes are absent and which are not. For instance, human 39 Hox genes.

Doubling of Hox clusters led to a more flexible gene expression since the conditions associated with gene statements involve protein outputs from all four Hox clusters. For instance, the condition in genetic program could have the form *IF [Hox-A-n or Hox-B-n] then...* This implies that the mutation of Hox gene in single cluster, which otherwise might be lethal, need not have any dramatic consequences. Doubling of the Hox cluster leads also to a multiplication of possible Hox patterns in breeding by a factor of 4 and hence to the large variation of the progeny, which is selective advantage. It is known that doublings of Hox clusters where followed by an emergence of large number of Hox-codes and only some of these codes have survived.

The presence of 4 Hox clusters in vertebrates could relate to four different tissue types corresponding to epithelial, connective, muscular and nervous tissues. Certainly this correspondence is not simply tissue-type $\leftrightarrow$ Hox cluster although there is some evidence that given Hox cluster dominates the expression of given tissue type under normal circumstances. For animals with 2 or 1 Hox clusters this kind of correspondence cannot hold true.

9.7.6 Characteristic Features Of Hox Genes

The characteristic features related to the expression of Hox genes give clues as how many-sheeted DNA is expressed.

Posterior Hox genes dominate over anterior Hox genes

Posterior Hox genes dominate over more anterior genes. For instance, if posterior Hox gene is removed to more anterior position the phenotype is more posterior. A simple illustrative example is based on a toy model of insect based on 3 Hox genes. The protein product of the Hox 1 gene instructs the formation of the head. The cells in the middle of body respond to both Hox1 and Hox2 genes. The protein product of Hox gene 2 is however believed to instruct the cells in this region not to not respond to Hox gene 1 so that Hox 2 genes determine the resulting structure. In the similar manner Hox 3 gene dominates over Hox 1 and Hox 2 genes in the tail part of the fictitious insect. Actually this picture is oversimplified but gives a good grasp of the idea.

This corresponds to a simple recursive control structure in genetic program.
P(n-1): IF protein coded by n: th Hox gene is the highest Hox protein present then DO B(n) ELSE DO P(n+1).
B(n): Form the n: th body part.

The problem is to understand how this control structure is realized. If Hox gene corresponds to program B(n) and does not serve as repressor of lower level Hox gene expression then it would seem that control structure must involve some "new genetics".

1. Hox genes select genetic programs. The mechanism of selection is based on attachment of the protein products to the control regions of corresponding genes could be such that gene program n is activated only if Hox proteins Hox-m $m \leq n$ are attached to the gene program.

2. One possibility involving introns in essential manner is that the activation of n: th Hox gene deactivates lower level Hox genes automatically. One possibility is that activation corresponds to the change of roles of introns and exons in Hox gene. Before activation Hox-n gene would be in "abnormal" state so that its intron parts would code protein. This protein could enhance the expression of the lower level Hox genes. After the activation this protein product would be absent and lower level Hox expression would not be enhanced anymore.

Hox expression domains are co-linear with the gene ordering inside Hox cluster

The development of embryo occurs in anterior to posterior (head to tail) direction. In all species hitherto examined, there is a strict correspondence between the ordering of the Hox genes inside clusters and the anterior boundaries of the expression domains along the head-tail axis of the developing embryo. Presence of the anterior boundary means that gene is not expressed above this boundary. The anterior boundaries of homologous genes in different clusters are same.

Establishment of Hox gene expression patterns in vertebrates

It is known that in vertebrates Hox gene expression patterns in developing embryo are established by waves propagating in posterior-anterior direction (tail to head). This means that there is also temporal co-linearity. Wave proceeds and ultimately stops at the anterior boundary of the expression domain. These anterior boundaries are characteristics of Hox genes and their ordering is the same as the ordering of Hox genes.

It is known that this pattern is not due to a forward spreading of cells. The presence of chemical signalling during the wave propagation is also excluded by the result of an experiment in which embryo was transversally sectioned [I130]. What happened that the wave propagated through the sectioning. Of course, it could be that chemical concentration gradient has been formed in earlier stage of development.

9.7.7 TGD Based Model For Hox Genes

The attempt to understand the known facts about Hox genes and their expression provides strong constraints on the general TGD based model of many-sheeted DNA and the results might be generalized to build more general models of gene expression during morphogenesis.

Hox cluster as a set of many-sheeted Hox genes?

Hox genes define division of developing embryo to slices of roughly same size. This suggests strongly that the largest space-time sheets associated with Hox genes correspond to the same p-adic prime $p \simeq 2^k$, k prime or power of prime. It could be that Hox genes are glued on same space-time sheet to form Hox cluster. Dominance of the posterior genes over anterior genes and spatial and temporal co-linearity reflect some kind of hierarchical ordering of Hox genes. This hierarchical ordering does not however seem to reflect the hierarchy of space-time sheets but gene program hierarchy.

Does activation of Hox gene involve a phase transition?

In vertebrates the activation of Hox genes occurs as a wave propagating from tail to head. A possible TGD based identification for the wave is as a phase transition leading to an expansion of a new space-time sheet associated with the many-sheeted Hox gene propagating in head to tail direction. This phase transition is determined solely by the internal state of the genome in given embryonic cell. In this phase transition the DNA space-time sheets would expand and join to form larger space-time sheet determining the size of the "imaginary disk" associated with the organ in question.

In Drosophila the length of DNA per single Hox gene plus its control region is about 10^{-5} meters. This suggests that the maximal space-time sheets of Hox genes correspond to $k = 173$, and that in activation this space-time sheet grows to its actual size. Of course, this growth could have occurred already in the segmentation stage. This would imply that the cells containing Hox genes

are glued together by flux tubes to form larger space-time sheets which later grow to space-time sheets corresponding to various organs.

How to understand basic facts about Hox gene expression?

There are several aspects involved with Hox gene expression which one should understand.

1. Co-linearity.
   Somehow the activation of n: th Hox gene leads to the activation of n+1: th Hox gene independently of what the n+1: th gene is. One possibility is that there is transcription factor gradient along the Hox gene which grows with time and gradually activates Hox genes in linear order. Perhaps enhancer is in question. Second possibility is that many-sheeted nature of Hox genes is crucially involved. Suppose that activation of Hox gene involves expansion of the largest space-time sheet associated with Hox gene. If the expansion of the space-time sheet of n: th Hox gene is necessary condition for the expansion of n+1: th space-time sheet, co-linearity follows automatically. This looks natural if the expansion of the Hox gene space-time sheet proceeds slowly along the Hox cluster so that expanding space-time sheet of n: th Hox gene is glued with that of n+1: th Hox gene

   This picture explains automatically also why the relocation of the Hox gene to a more anterior position makes Hox expression more posterior. The anterior boundaries in Hox clusters located in different chromosomes are the same. This suggest that the control for the beginning of the Hox expression program is associated with the space-time sheet representing entire embryo. Control could involve classical field affecting acting via enhancer or silencer type transcription factors whose effect is known to be not purely chemical.

2. Temporal co-linearity.
   This is present in vertebrates but not in Drosophila. Chemical signalling between cells cannot explain temporal co-linearity and it must be due to the independent development of the cell genomes. The simplest explanation is that there is lag in the activation time for the genetic program activating Hox genes increasing monotonically as a function of the distance along the anterior-posterior axis. This dependence could be generated by a gradient of corresponding transcription factor concentration, perhaps created already in maternal period. This gradient should be generated by a DNA sequence located at the $5'$ end of the Hox cluster so that transcription factor in question must be repressor: activation takes place when the concentration is subcritical.

3. The presence of the anterior boundaries.
   The presence of the anterior boundaries is most naturally due to determination of cells occurred before the activation of Hox genes. Segmentation genes indeed force various segments to different branches of genetic program and it is quite plausible that the activation of the Hox genes depends on segment. What is needed that the Hox genes above anterior boundary are too far from criticality for the activation to occur. It is also possible that cells in anterior end of the embryo generate repressor concentration which gradually grows and shifts anterior boundary in posterior direction during morphogenesis. If the expansion of space-time sheets associated with Hox genes is responsible for activation, this expansion should stop at n: th gene in n: th expression domain. It is not clear why this should occur without the proposed mechanism.

4. Posterior prevalence.
   An explanation in terms of the control mechanisms of gene programs activated by Hox genes has been already considered. Second explanation for posterior prevalence is that the expansion of the space-time sheet associated with Hox genes to a single space-time sheet common to first n Hox genes somehow represses the expression of all Hox genes expect n: th one. Perhaps only the gene on the boundary of this space-time can be active.

Quantum model for the expression of Hox genes

There are too much unknown factors to allow a construction of a detailed quantum model for the situation. What however seems clear that the differences of the vacuum frequencies representing

potential differences over Josephson junctions should effectively appear as transcription factors and control parameters. A quantum model possibly catching some aspects of Hox gene expression might involve at least the following assumptions.

1. Assume that genes along chromosome are characterized by vacuum frequencies ω_i. This frequency does not depend on gene but only on its position in the chromosome. This assumption guarantees spatial co-linearity. The dependence of the gene's vacuum frequency on the position of gene along the chromosome could be understood if chromosome forms linear join along boundaries/flux tube condensate with Josephson junctions connecting subsequent gene space-time sheets. This would mean that there is electric field along the chromosome. These Josephson junctions could be involved with the activation of the gene by the control DNA section preceding it. Also the effect of the enhancers and silencers might involve resonant Josephson current between control section of DNA and gene leading to the wake-up of the gene.

2. The vacuum frequency Ω characterizing the size of the growing organism increases with time and Ω changes in a phase transition like manner step by step. Temporal co-linearity can be understood if there is some (possibly phase) gradient along the growing organism implying that the phase transition leading to the increase of Ω proceeds from tail to head. The gradient could act like a concentration of a chemical suppressor decreasing in head-to tail direction and established already before the Hox gene expression started.

3. The space-time sheet of the organism and gene space-time sheets form weakly coupled super conductors and potential differences over the Josephson junctions serve as transcription factors. When the frequency $\Omega - \omega_i$, which corresponds to potential difference eV, equals to critical frequency, resonant currents are generated waking-up i: th gene and activating it. Given gene is active only during the time interval when $\Omega - \omega_i$ is critical. With the assumed dependence of ω_i on the position of gene, this implies spatial co-linearity and posterior prevalence.

Chapter 10

Model for the Findings about Hologram Generating Properties of DNA

10.1 Introduction

The findings of Gariaev's group include the rotation of polarization plane of laser light by DNA [I86], phantom DNA effect [I87], the transformation of laser light to radio wave photons having biological effects [I89], the coding of DNA sequences to the modulated polarization plane of laser light and the ability of this kind of light to induce gene expression in another organisms provided the modulated polarization pattern corresponds to an "address" characterizing the organism [I86]. and the formation of images of what is believed to be DNA sample itself and of the objects of environment by DNA sample in a cell irradiated by ordinary light in UV-IR range [I108]. This chapter represents an article which is an outcome of a collaboration with Peter Gariaev and I want to thank Peter for an enjoyable and instructive co-operation. The article will be published in DNADJ (DNA Decipher Journal) in January 2011 and can be found as preprint in Scireprints archive (see `http://scireprints.lu.lv/160/`) [K1].

10.1.1 The Notion Of Wave Genome

Peter Gariaev and collaborators have introduced the notion of wave genome [I86] requiring the coding of DNA sequences to temporal patterns of coherent em fields forming a bio-hologram representing geometric information about the organism. Code could mean that nucleotide is represented by a characteristic rotation angle for the polarization plane of linearly polarized laser radiation scattering from it. The experiments of Peter Gariaev's team [I89] suggest that this kind rotation is induced by chromosomes by a mechanism which to my best knowledge is poorly understood. Other open questions concern the precise identification of the substrate of the bio-hologram, of the reference wave and of information carrying wave, and of the mechanism making possible (quantum) coherence in macroscopic length scales.

The reading of the DNA sequence to a radiation pattern is assumed to rely on the propagation of an acoustic soliton along DNA [I86]. Whatever this process is, one should also identify the reverse process inducing the activation of the genome as the target organism receives the radiation coding for the DNA provided the genetic "address" is correct. One should also identify the mechanism transforming laser radiation to radio-waves at various frequencies as well as the mechanism creating what is believed to be the image of DNA sample and replicated images of some instruments used in experiment.

10.1.2 Hologram Like Radiation Patterns Generated By DNA

In this article one particular experiment, namely the already mentioned experiment involving the formation of two kinds of strange replica structures resulting when DNA sample is radiated by

red, IR, and UV light using two methods by Gariaev's group [I108] will be discussed. The original interpretation of the image produce by first method is as a replica image of DNA sample. This interpretation can be challenged. The second image is interpreted as a hologram image of the environment. In the following the interpretation of these images in TGD framework is discussed.

The first method produces what was originally interpreted as replica images of either DNA sample or of five red lamps used to irradiate the sample. Second method produce replica image of environment with replication in horizontal direction but only at the right hand side of the apparatus. Also a white phantom variant of the replica trajectory observed in the first experiment is observed and has in vertical dir

10.1.3 Basic TGD Based Notions Involved With The Model

In this article a model explaining the characteristic features of the replica patterns is developed. The model is inspired by Topological Geometrodynamics (TGD), the recent state of which is discussed in Prespace-time Journal [L7, L8, L11, L12, L9, L6, L10, L1]. TGD is a proposal for a unified theory of the fundamental interactions based on a generalization of the notion of space-time having perhaps its most important consequences at the level of living systems. TGD inspired theory of consciousness and of quantum biology is discussed in the articles [L5, L4, L3] of Journal of Consciousness Research & Exploration. The model differs in many respects from the general model of proposed by Peter Gariaev and collaborators [I86] but shares with it the vision about holograms as a basic element of information processing in living systems at DNA level.

The basic notions are magnetic body, massless extremal (topological light ray), the existence of Bose-Einstein condensates of Cooper pairs at magnetic flux tubes, and dark photons with large value of Planck constant for which macroscopic quantum coherence is possible. Also the hypothesis that the differences of zero point kinetic energies for space-time sheets with different p-adic length scales define universal metabolic energy quanta is used in the model for pumping of radiation energy to the system. The hypothesis is that the first method makes part of the magnetic body of DNA sample visible whereas method II would produce replica hologram of environment using dark photons and also the phantom image of the flux tubes becoming visible by method I.

Replicas would result by mirror hall effect in the sense that the dark photons would move back and forth between the part of magnetic body becoming visible by method I and serving as a mirror and the objects of environment serving also as mirrors. What is however required is that not only the outer boundaries of objects visible via ordinary reflection act as mirrors but also the parts of the outer boundary not usually visible perform mirror function so that an essentially 3-D vision providing information about the geometry of the entire object would be in question. Many-sheeted space-time allows this.

The presence of the hologram image for method II requires the self-sustainment of the reference beam only whereas the presence of phantom DNA image for method I requires the self-sustainment of both beams. Non-linear dynamics for the energy feed from DNA to the magnetic body could make possible self-sustainment for both beams simultaneously. Non-linear dynamics for beams themselves could allow for the self-sustainment of reference beam and/or reflected beam. The latter option is favored by data.

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` [L19].

10.2 Observations

Two methods are involved to produce images with replica structure in the experiments of Gariaev's team. The detailed experimental arrangement and results of these experiments are described in [I108]. Reader can get a concrete idea about the experiments from the figures at the end of this article.

For both methods one uses sources of red and IR photons emitted by diodes as well as sources of UV-B and UV-C photons (for a schematic representation of the experimental apparatus **Fig. 10.13**). The wave lengths and energies for red and IR photons are given by the following equations.

$$\begin{array}{lll} \lambda/nm & 650 & 920 \\ E/eV & 1.91 & 1.35 \end{array} \tag{10.2.1}$$

The wave-length and energy intervals for UV-B and UB-C radiation are given by the following equations.

$$\begin{array}{lll} Energy\ range & [\lambda_1, \lambda_2]/nm & [E_1, E_2]/eV \\ & & \\ UV-B & [315, 280] & [3.94, 4.43] \\ UV-C & [280, 100]] & [4.43, 12.40] \end{array} \tag{10.2.2}$$

1. In method I red, IR, and UV-B and UV-C beams are present all the time. During irradiation is one detects what are called DNA replica trajectories (**Figs. 10.3** and **10.4**) These roughly vertical tubular structures (or less probably, planar structures orthogonal to the preferred horizontal direction) have grainy structure (**Fig. 10.3**). Replica trajectories decompose to five sub-trajectories which probably correspond to the five red diodes irradiating DNA directly (**Fig. 10.4**). One could interpret the replica trajectories as images of DNA sample or of red diodes created by the DNA sample.

   Long-lived red DNA replica trajectories called phantom DNA trajectories are present also when the irradiation has ceased (**Fig. 10.5**). The distributions of brightness for these images in RGB model are represented in **Fig. 10.6** representing especially clearly the structure of the trajectories.

2. In method II same beams are present but only periodically. The replicas appear when the beams are not on and are in horizontal direction representing environment (**Fig. 10.2**). The basic feature is that the objects of environment are replicated in horizontal direction with distance defined by the horizontal size of the object so that fractal structure results. There are also phantom DNA replicas which are white and to the left of DNA sample and could correspond to the red replicas seen by method I (**Fig. 10.2**). These structures are thicker than than the red replica trajectories of method I.

   What is remarkable that the replicas representing environment carry information about the geometry of the *entire* objects rather than that for the outer surface of these objects seen in reflection: a kind of 3-dimensional vision seems to be in question which cannot be explained in terms of ordinary holograms alone. The vertical region in which replicas are obtained corresponds to the height of the roughly vertical replica structures produced by method I.

   What is equally remarkable is that the replicas appear only at the right hand side of the system but not at the left hand side. Strangely, the touching of the DNA sample however shifts replicas to the left after which they disappear in about 5 to 8 seconds (**Fig.** s **10.7** and **??**). The color of the replicas can be white, reddish, red and even blue. It is not quite clear whether the left replicas are mirror images of right replicas or images of the left hand side of the environment.

In both cases the key question is whether the replica trajectories represent real physical objects or whether they are analogous to a sequence of mirror images resulting when one has object between two mirrors and repeated reflections create a sequence of images replicas (mirror hall effect).

10.3 Model For The Findings

The model for the findings is based on TGD inspired model of quantum biology. The key physical input of the TGD based model are the notions of magnetic body [K53] and of massless extremal (ME) or topological light ray [K68], and the identification of dark matter in terms of a hierarchy of Planck constants [K38] assumed to play a key role in living matter. These notions are described briefly in [L3]. A more detailed descriptions can be found in online books about TGD: for magnetic body in [K53], for MEs in [K68] and for the hierarchy of Planck constants in [K38].

10.3.1 Basic Notions And Ideas

The key notions and ideas of the TGD inspired model are the same as of the model discussed in [K104] as a possible framework for understanding the findings of Gariaev's team. Only the treatment is considerably more detailed.

1. In TGD inspired theory of quantum biology one assigns to all biological structures magnetic bodies which use biological bodies as sensory receptors and motor instruments. This is assumed to hold true for DNA nucleotides, DNA strands, and even DNA sample itself so that an onion like hierarchy of magnetic bodies results. The basic vision is that magnetic flux sheets traversing through DNA integrate the DNAs of various nuclei to super DNA and that this occurs at level of organs, organisms and even populations and makes possible coherent gene expression responsible for the ability of living organisms to behave as single unit and also co-operate [K3, K35]. The magnetic flux quanta and flux sheets can also end to the objects of the environment and this is essential for the model to be proposed.

   The matter at flux quanta is identified as dark matter and has Planck constant which is integer multiple of the ordinary one, and can be quite large so that macroscopic quantum coherence becomes possible. This makes possible the formation of holograms and mirror hall effect since the dark counterparts of the ordinary photons can have wave length much longer than the size scale of the experimental apparatus.

   Although the DNA preparation in the experiments of Gariaev's team is formed from a cellular structure by a violent chemical process removing proteins and cellular and nuclear membranes, the magnetic body of DNA sample could remain intact so that a natural hypothesis is that magnetic body are involved with the formation of both DNA replica trajectories and hologram like replica trajectories.

2. Topological light rays (MEs) are tubular structures very much analogous to laser beams. They carry radiation moving with light velocity and without dispersion and dissipation in *single* space-time direction that they are ideal for communication and control purposes. This linear superposition of only modes with parallel 4-D wave vectors is a key distinction from Maxwell's electrodynamics and due to non-linearity of the fundamental variational principle. More precisely, if one changes the direction of the 4-D wave vector opposite, both 3-D wave vector and frequency change sign so that the counterpart of phase conjugate laser light is in question. Hence one would have superpositions of beams and their phase conjugates having interpretation as positive and negative energy signals traversing in opposite spatial and temporal directions. At quantum level one might perhaps speak positive and negative energy photons.

   MEs could topologically condense at magnetic flux quanta and would be accompanied by the TGD counterparts of Alfven waves [F3] representing transverse geometric oscillations of the magnetic flux quanta (sheets and tubes) regarded as space-time surfaces. It would be very natural to assume that topological light rays serve as correlates for the photons reflected from DNA sample to its magnetic body. In rather precise sense these photons would represent the scaled variant of EEG used by magnetic body to control brain and receive information from brain in TGD based model of brain.

10.3.2 Method I

The details of method I and the absence of the image of the environment (**Fig. 10.3**) in this case do not encourage hologram interpretation. The interpretation coming first in mind is that the DNA replica trajectory is realized at magnetic flux tubes serving as a screen. Flux sheets orthogonal to the plane of the images cannot be excluded but are less not plausible. The simplest assumption is that the photons of red light travel scattered from DNA sample to the magnetic flux tube like structures defining the screen along MEs topologically condensed at magnetic flux sheets traversing through DNA strands which are partially un-winded and have length of order 1 cm. Red light could transform to dark photons with large Planck constant with wavelength of order 1 cm but at the magnetic body it would transform partially back to visible photons. This is however not necessary. Also UV and IR photons would interact with the DNA sample and could

provide the metabolic energy allowing also to amplify the signal. Also UV and IR photons could transform to dark photons and define part of the "EEG" of the DNA sample.

10.3.3 Method Ii

For method II the interpretation in terms of a hologram like structure resulting when light traveling in horizontal direction is reflected from the objects of the environment is suggestive.

1. For white cable like structures left from DNA sample referred to as phantom DNA replicas the grainy replica structure is actually not present (**Fig. 10.2**) so that phantom DNA replica is perhaps not the proper term. As in the case of method I these structures could be interpreted as images of the magnetic body serving as the hologram substrate. Since red light source is off, only the white light emitted by the DNA substrate is present. These structures are wider than the red DNA replicas and a rough estimate for their thickness is about 1 cm so that the interpretation as a flux tube of magnetic body is suggestive. The interpretation of the signal as counterparts of bio-photons [I99] generated when dark photons transform to ordinary visible photons is suggestive.

2. Hologram interpretation for the replica of environment (**Fig.** 10.2) requires the system generates the reference beam prevailing for some time although the irradiations are turned off. The reflected beams due to the irradiation would disappear as the irradiation is turned off so that the reference beam can generate the hologram image.

3. The simplest assumption is that there are horizontal flux tubes or sheet(s) in the plane defined by the vertical and horizontal directions and that the part of the magnetic body corresponding to DNA replica trajectory serves as source of dark photons with large $\hbar$ [K38], which travel to the right in horizontal direction and along flux tubes connected to the outer surfaces of the objects of environment. If the dark photons emanate from the structures visible as phantom DNA replica, one can understand why the image is from the right hand side.

4. Similar connections to other living organisms would explain the original observations of Gurwitsch about mitogenetic radiation at UV frequencies [I113]: the UV radiation would represent decay products of dark variants of UV photons. One could also interpret bio-photons [I99] at visible wavelengths as decay products of their dark variants with much longer wave lengths. These photons could produce also bunches of EEG photons for large enough value of $\hbar$ [K35]. Also the findings of Gariaev's group about the transformation of laser light irradiating DNA to a radiation in a wide range of frequencies extending at least down to 10^4 Hz (corresponds to a wavelength of about 10 km) and having biological effects [I89] could be interpreted in terms of long wave length dark photons with energies of visible photons. The role of low frequencies down to 10^4 Hz at least in water memory [I82, I83] suggests that the basic mechanism of water memory is based on dark radio wave photons. The recent findings of the group led by HIV nobelist Jean-Luc Montagnier [I96] relating to water memory suggest an interaction between DNA samples based on radiation and also a new non-chemical representation of genetic code in terms of electromagnetic radiation patterns proposed also by Gariaev's team [I86, I89]. TGD approach suggests besides field representation based on MEs [K47], a representation in terms of flux tubes connecting DNA and lipids of cell membrane [K3], and a representation of genetic code in terms of the states of dark nucleons [K106]. Computer science inspired view indeed suggests DNA provides only one of the many representations of the genetic code.

5. What differentiates the hologram from the ordinary one is that reflections occur from the entire outer surfaces- not only from the outer surface visible in ordinary sense but also from the "inner side" of the part not usually visible so that information about entire 3-D geometry is obtained (**Fig. 10.2**). Without this assumption it is difficult to understand the replication in the scale of the replicated object. The repeated travel back and forth along these flux tubes or sheets would produce mirror hall effect and the observed replica structure could be understood.

6. A possible reason for why replicas are horizontal is that the magnetic body of DNA sample receives information from the environment and the objects are of environment tend to be in the horizontal direction. Phantom DNA replicas which might relate to phantom DNA effect [I87] discovered also by Gariaev's group appear only at the left hand side of the DNA sample and if they represent ordinary images of the hologram substrate and serve as mirrors, the appearance of the hologram replicas at the right hand side only can be understood. These images would result as dark photons emitted by the hologram substrate transforms to visible light.

   What happens in phantom DNA effect is that laser light scatters from the chamber weakly even after the DNA sample has been removed. The simplest explanation could be that some fraction of DNA leaves their magnetic bodies to the sample and that the scattering involves these magnetic bodies already in the original situation. Also water memory [I82, I83, I96] could be due to the fact that for some fraction of the biological molecules originally present in the solution before dilution leaves the magnetic bodies in the sample and generate the radiation responsible for the biological effects as cyclotron radiation [K47].

7. The hologram image would result as the photons of the reflected reference beam transform back to photons of visible (and possibly UV and IR) light. The reflection preserves only the vertical momentum of photon parallel to the flux tube so that reflections occur also in the direction of the camera. The photons in question need not correspond to single wave length. The UV radiation necessary for the experiment might serve as a metabolic energy source allowing to generate dark photons but it could also transform to dark photons defining the hologram. The longitudinal coherence length [I114]

$$\xi = \frac{c}{\Delta f} = \frac{\lambda_d^2}{\Delta\lambda_d} = r\frac{\lambda^2}{\Delta\lambda} \quad , \quad r = \frac{\hbar}{\hbar_0}$$

   of dark photons must be larger than the size scale $L \sim 20$ cm of the experimental apparatus in order to produce mirror hall effect. From the assumption that the size scale $l \sim 1$ cm of the grains of the replica trajectory is of order $l \sim r\lambda$, one obtains the estimate $r = 15 \times 2^{10}$. This gives $\lambda/\Delta\lambda \sim 20$, which looks rather reasonable value.

The transformation of the right-handed mirror hall image to left handed as the DNA sample is touched should be also understood.

1. The first question is whether the effect of touch (**Figs. 10.7** and **10.8**) is mechanical or biological. The proposed model encourages to consider the possibility that the magnetic body assignable to the hand or finger touching the sample generates the external irradiation generating dark photons needed to generate a replica hologram from the left hand side of the apparatus. When the finger is removed from the vicinity of the sample, one expects that the hologram disappears as it indeed does within 5-8 seconds. The mechanical instability induced by the direct touch could be the reason for the disappearance of the right sided hologram. Also the intensity of the irradiation from the magnetic body assignable to hand is expected to be stronger than the original reference beam so that the hologram is transformed to left-sided hologram. This explanation could be tested by touching the sample from another side to see whether the hologram remains right sided in this case.

2. One can imagine also alternative but more complex explanation not favored by Occam's razor. What comes in mind that the reference beam needed for the hologram and generated by DNA sample of the magnetic body is transformed to its unstable phase conjugate and thus travels from left to right and produces a left sided replica hologram. An open question is whether this hologram is from left hand side of the system or a mirror image of the hologram from right hand side. Perhaps this could be tested.

   DNA strands and their conjugates should correspond to separate flux sheets and one can wonder whether the double DNA strand maps to a doublet of magnetic bodies (note the analogy with two brain hemispheres and EEG) and whether left-right dichotomy could correspond to DNA-conjugate DNA dichotomy. If so, then touching would lead to the disappearance of DNA reference beam and the generation of its conjugate beam assignable to conjugate strand of DNA and perhaps scattering from the conjugate hologram also formed in the process.

10.4 The Realization Of The Hologram At The Level Of Magnetic Body

How the reference beam is generated and how the hologram substrate is realized? These are the basic questions to be answered. Reference beam should be generated by the magnetic body itself and/or by DNA sample since it exists in absence of irradiation. Magnetic body should define the photosensitive substrate and the thickness of the analog of the photographic plate should be of the order of scaled up wavelength in order to achieve this. Note that in the case of EEG photons similar mechanism would mean that the size for the analog of the photographic plate is of order Earth size scale!

10.4.1 How The Reference Beams And Reflected Beams Are Generated?

The explanation for the replica assumes that the reflected beams are horizontal. Reference beams should be such that there exists a mechanism taking care the that they are preserved after the irradiations cease. The mechanism generating the reference beam would be most naturally the coherent decay of the excited state of a Bose-Einstein condensate. This condensate must be however assigned with some other structure than hologram substrate itself.

One can distinguish two DNA replica trajectories near DNA sample and there are even more of them at higher height (**Fig. 10.3**. The decay of the first replica trajectory could provide reference beam and reflected beam for the second replica trajectory acting as hologram substrate and vice versa. This mechanism works for an arbitrary number of hologram substrates and could be at work at red, IR, and UV wave lengths. The mechanism is actually the same as the one generating ordinary laser beams and skeptic can of course ask whether the large value of Planck constant is absolutely necessary.

The replica hologram obtained by method II involves several colors. The figures about the holograms show the presence of red light, reddish or white light, and also blue light and one must understand also this. Holograms are constructed using monochromatic laser light. The reading of the hologram is however possible using even white light if the reference beam is orthogonal to the hologram substrate since in the idealization that hologram is infinitely thin, the information about the wavelength of reference beam is completely lost in this case. The proposed model for the generation of reference is consistent with the orthogonality.

The picture that emerges would be following.

1. At least the incoming red beam is transformed after the passage through the sample to a beam with large value of Planck constant and wavelength of order say.2-.5 m corresponding to the size of the region appearing in the hologram. It is quite possible that also UV and IR photons transform to dark photons. At the magnetic flux tube this beam of dark photons is split to two pieces defining reference bream and the beam reflected from the objects of the environment. All these beams are nearly horizontal. The reflected beam and reference beam recombine and form a hologram substrate defined by magnetic flux tubes assigned to the DNA replica trajectory.

2. The cyclotron Bose-Einstein condensates at magnetic bodies function as analogs of lasers. Instead of the excitations of atomic states one has excitations of cyclotron states of a Bose-Einstein condensate with a large value of Planck constant. The excitation of these states requires pumping of energy. The simplest possibility is that both UV, IR, red, and IR light pump energy to the respective modes so that one would have multi-laser operation. The magnetic body is predicted to have a hierarchical fractal structure with magnetic fields whose strengths correspond to the p-adic length scale in question with p-adic length scales coming as half octaves of basic scale which conveniently can be taken 10 nm defining the thickness of cell membrane (for p-adic length scale hypothesis, which forms one of the corner stones of TGD based particle physics and of quantum biology see [L7, L8, L11, L12, L9, L6, L10, L13]. These irradiations would excite different parts of the magnetic body giving rise to a fractal hierarchy of holograms. The camera operating at visible wave lengths would not allow to see UV and IR holograms.

3. It is important to notice that the presence of only say red beam of light is not r enough to generate the hologram so that an interaction between these irradiations must be present. Some of the beams could act as control signals activating the DNA or as sources of metabolic energy (say UV beams).

4. The holograms appear periodically for method II [I108]: **Figs. 10.9**, **10.10**, **10.11**, **10.12** at the end of the article illustrate what is involved. The periodic irradiation of the sample certainly induces a periodically appearing hologram image: when all irradiating beams are turned on, the conditions for the appearance of hologram are not satisfied and hologram disappears. The period is however considerably longer than the time interval between irradiation periods. This suggests a threshold for the effect.

   When the amount of pumped energy reaches a threshold, the intensity of the reference beam increases dramatically and the hologram becomes visible. This kind of effect requires a non-linear dynamics. The simplest model would be in terms of a potential containing the net value of the pumped energy as a parameter. As this parameter exceeds a threshold value, a phase transition the equilibrium position of the system would change from that with a vanishing reference beams to that with a large reference beam and the energy stored to the system would be utilized. DNA sample would be the natural storage of the energy.

10.4.2 A Simple Model For The Dynamics Of Pumping And Sustainment Of Dark Photon Beams

The basic question is what the pumping of energy could mean at the level of DNA. It seems clear that at least part of the pumped energy is transformed to metabolic energy in turn transformed to dark photons. It is also possible that the chemical energy of stored in DNA molecules is transformed to metabolic energy. The existence of a hierarchy of universal metabolic energy quanta predicted by TGD provides the physical basis of the model.

One should also have a qualitative model for the transformation of the energy of radiation to metabolic energy and to the self sustainment of the dark photon beams.

1. The basic idea is simple. The irradiation kicks particles in DNA to higher energy state and these states decay to the ground state by emission of dark photons making allowing to realize the reference beam for holograms during reading period and both reflected and references beams during irradiation period.

2. For method I both the reference beam and reflected beam remain when irradiation ceases and give rise to the red phantom DNA replica (**Fig. 10.5**). For method II the presence of hologram image (**Fig. 10.2**) means that only reference beam is sustained. Self-sustainment requires non-linear dynamics. This dynamics could appear either at the level of DNA sample or at the level of the reference beam and reflected beams. For method II the white cable like structures appearing to the left of DNA sample could also correspond phantom DNA replica. They cannot however correspond to hologram like mechanism but ordinary radiation emitted by the hologram substrate.

3. The first possibility (option I) that the non-linear dynamics is realized at the level of DNA. DNA might be able to liberate chemical energy as metabolic energy or store the energy of irradiation and then liberate it. It is however difficult to understand why only the reference beam is sustained in method II. Both beams should be present if they result by a splitting of a beam coming from DNA meaning the absence of replica hologram. Internal consistency would require giving up hologram interpretation.

4. Second possibility (option II) is that non-linear dynamics is realized at the level of reference beam and reflected beams. For method II this dynamics could lead to a self sustainment in the case of reference beam if it is more intense than the reflected beams. For method I the irradiation lasts much longer and both reference beam and reflected beam could be sustained and one would not obtain hologram image but only phantom DNA replica image.

The following qualitative model has same general form for both options.

p-Adic length scale hypothesis and hierarchy of metabolic energy quanta

If one takes seriously the TGD inspired model for metabolic energy quanta, the irradiation would kick charged particles from larger space-time sheets to smaller ones so that the energy would go to the zero point kinetic energy plus surplus. The particles would drop back to the larger space-time sheets emitting the surplus zero point kinetic energy in this process as dark photon going to the magnetic flux tubes to be used to build reference beams and reflected beams for the holograms.

The kicked particles could be electrons or protons but electrons are more plausible candidates.

1. The nominal value of zero point kinetic energy given by

$$E_0 = \frac{3\hbar^2}{2mL^2} , \tag{10.4.1}$$

and corresponds to zero point kinetic energy for a particle in box with side of length L.

2. Possible values of L can be estimated by assuming $L = L(k)$, with $L(k)$ given by the p-adic length scale hypothesis stating

$$L(k) = 2^{(k-151)/2} L(151) , \tag{10.4.2}$$

where electron Comptonlength $L_e(151) = \sqrt{5}L(151) \simeq 10$ nm corresponds to Gaussian Mersenne prime $M_{151,G} = (1+i)^{151} - 1$, which is one of the Gaussian Mersennes $M_{k,G}$, $k = 1151, 157, 163, 167$ between cell membrane thickness 10 nm and length scale 2.5 μm which is roughly one half of the size scale of cell nucleus. For $k = 148$ one obtains $E_0(148) \simeq .5$ eV which is the nominal value of metabolic energy quantum. Other zero point kinetic energies would come as octaves of $E_0(148)$ so that one has has the series (..., .25, .5, 1, 2, 4, ..) eV. Nominal values are in question: the variation can be at least 10 per cent around the nominal value and is due to the fact that in reality space-time sheets do not have the geometry of cube and because the particles inside space-time sheets are not free.

3. Metabolic energy quanta correspond to the zero point kinetic energies liberated as particle drops from space-time sheet characterized by k_1 to $k_1 + \Delta k$ and are given as differences

$$\Delta E_0(k, k+\Delta k) = \frac{3\hbar^2}{2mL^2(151)} 2^{-k+151}(1 - 2^{-\Delta k}) . \tag{10.4.3}$$

This gives a geometric series of metabolic energy quanta for each value of k. Two cases are of special interest: dropping next space-time sheet in the hierarchy ($\Delta k = 1$) and dropping to very large space-time ($\Delta k \to \infty$).

$$\begin{aligned} \Delta E_0(k,1) &= \frac{3\hbar^2}{2mL^2(151)} 2^{-k+151} , \\ \Delta E_0(k,\infty) &= \Delta E_0(k-1,1) = \frac{3\hbar^2}{4mL^2(151)} 2^{-k+151} . \end{aligned} \tag{10.4.4}$$

4. Note that the energy levels form a cascade converging to $\Delta E_0(k,\infty) = \Delta E_0(k-1,1)$. The scaling $\hbar = r\hbar_0$ of Planck constant does not affect the spectrum of metabolic energy quanta if $L(k)$ scales as $L(k) \to rL(k)$.

5. The following equation lists the three p-adic length scales, which are possible for the radiation sources used assuming that $\Delta k = 1$ transitions dominate.

$$\begin{array}{llll} k & 145 & 144 & 143 \\ \Delta E_0(k,1)/eV & 2 & 4 & 8 \\ \lambda/nm & 620 & 310 & 155 \\ L_e(k)/nm & 1.23 & .88 & .625 \end{array} \tag{10.4.5}$$

   The 2 eV metabolic energy is five percent larger than the energy 1.91 eV assignable to 650 nm wavelength of the red light used in irradiation. These wave lengths would be preferred but in principle entire range of metabolic energy quanta is allowed and if one assigns metabolic energy quanta to the transitions $\Delta k \to \infty$ the values of k in the equation are scaled down by one unit: $k \to k-1$. The p-adic length scales correspond to length scales naturally associated with DNA.

   In the case of proton the length scales would be obtained by the replacement $k \to k - 11$ and would be considerably below the atomic length scale $L_e(137)$ for the ordinary value of Planck constant and dark protons would be required.

Comment: It has turned that this view about metabolic quanta can be modified without changing the values of metabolic energy quanta. Instead of dropping of particles to a larger space-time sheet the p-adic prime assignable to the space-time sheet itself could change leading typically to a reduction of single particle energies since the size of the space-time sheet increases. Quantum numbers do not change in this transition if it takes place adiabatically. This applies not only to particles in box but also to cyclotron states: in this case the strength of the magnetic field is reduced to conserve magnetic flux as p-adic prime increases and induces the increase of the flux tube thickness. This yields same predictions as the earlier model explaining the quantal effects of ELF radiation on vertebrate brain. The nice feature of this mechanism and its variants [K52] is that the transition liberates energy of a large number of particles simultaneously. This is not obvious for when particles drop to larger space-time sheets.

Linear model for the pumping of energy

If one assumes that the non-linear behavior responsible for self-sustainment is realize at the level of the reference beams and reflected beams the model for pumping of energy to DNA sample can assumed to be linear. The simplest model for the pumping involves only two space-time sheets. The proper variable would be either the number N of charged particles -presumably electrons- and/or net zero point kinetic energy feed to the smaller space-time sheet. One has just population dynamics for the numbers of electrons at the two space-time sheets involved.

1. The equations for the population dynamics have the general form

$$\begin{aligned} \frac{dN_1}{dt} &= k_0(t)N_2 - k_1(t)N \ , \\ \frac{dN_2}{dt} &= -k_0(t)N_2 + k_1(t)N \ , \end{aligned} \tag{10.4.6}$$

   The first term on the right hand side corresponds to the energy feed from irradiation and second term the energy leakage through the dropping of the particles back to the smaller space-time sheet.

2. If the N_2 is very large it can be taken as constant not affected by the process and with an obvious redefinition of $k_0(t)$ one can write

$$\frac{dN_1}{dt} = k_0(t) - k_1(t)N_1 \ . \tag{10.4.7}$$

The general solution of the equation is

$$N_1(t) = N_0 exp(-\int k_1 dt) + \int_0^t N_1 exp(\int_0^t k_1 dt) k_0(t) dt \ . \tag{10.4.8}$$

As noticed, this model cannot explain self-sustainment in terms of metabolism.

A catastrophe theoretic model for the self-sustainment

The self-sustainment of the beams requires non-linear dynamics. The non-linearity could be assigned with the pumping of energy to DNA by irradiation and would mean the addition of non-linear terms to the population dynamics of electrons (Eq. 10.4.7). This model does not however allow to distinguish between reference beams and reflected beams. The same formal model however applies also to the dark reference beams and reflected beams by re-interpreting number N of electrons as the number of photons in the beam. The following model is only an attempt to characterize the situation qualitatively and does not depend on the interpretation of N. The two alternative interpretations will be referred to as options I and II.

1. The basic equation is

$$\frac{dN}{dt} = P_3(N, k_0) = k_0(t) - k_1(t)N + k_2(t)N^2 - k_3(t)N^3 \ . \tag{10.4.9}$$

The parameters $k_i(t)$ are assumed to be slowly varying in the time scale of the dynamics for N. In catastrophe theoretic setting [A13] k_i *resp.* N would be called control parameters *resp.* behavior variable. Depending on option N denotes either the number of electrons kicked to a smaller space-time sheet of photons in the analog of laser beam.

   (a) For option I $k_0(t)$ characterizes the rate at which the irradiation kicks electrons to the smaller space-time sheet. For option II the interpretation is as a rate with which photons in the dark analog of laser beam are produced by irradiation. One can assume that $k_0(t)$ is constant during periods of irradiation and is small and vanishes when there is no irradiation.

$$\begin{aligned} k_0(t) &= k_0 \text{ during irradiation} \ , \\ k_0(t) &= 0 \text{ in absence of irradiation} \ . \end{aligned} \tag{10.4.10}$$

   (b) For option I the term $-k_1N_1$ corresponds to the dropping of the electrons back to the large space-time sheets. For option II it corresponds to the leakage and absorption of photons from the beam.

   (c) For option I the presence of k_2N^2 can make possible self-sustained metabolism and therefore also that of dark photon beams. DNA itself can somehow kick the electrons to smaller space-time sheets. This could be due to the liberation of metabolic energy from DNA, which cannot continue indefinitely so that $k_2(t)$ must go to zero in some time scale of the order of the time period between successive shots (few seconds). For option II this term correspond to non-linear self-amplifying interaction of laser beams and could be due to a resonant interaction of beams associated with different parts of the magnetic body.

(d) The term $-k_3N^3$ is necessary in order to avoid endlessly increasing N, which is definitely something non-realistic.

2. By construction the system realizes cusp catastrophe [A13] describing the simplest possible situation in which some parameter region of parameter space allow 3 or only 1 root to the stationarity condition $P_3(N,k_0)=0$ so that one has a phase transition like behavior. The following considerations show that if $P_3(N,0)$ allows three non-negative roots and $P_3(N,k_0)$ only one positive root, then sufficiently many and sufficiently long irradiation periods allow to achieve a self-sustaining situation, which lasts as long as $k_2(t)$ characterizing self-sustainment remains large enough. After this a phase transition to a phase characterized by a rapid decrease of N, occurs.

3. One can concretize the situation by imagining that the system climbs to a mountain during the irradiation periods and slides down when the irradiation is off in the case that one has

$$R \equiv \lim_{t\to t_f,+} dN/dt(t) = P_3(N(t_f),0) < 0 \ . \tag{10.4.11}$$

Here t_f denotes the value of time when irradiation ends. For $R>0$ the climbing up continues spontaneously but with a slower rate.

4. Quite generally, $P_3(N,k_0)$ can have $n=0,1$ or $n=3$ zeros in the region $N\geq 0$. $P_3(N,0)$ has always zero at origin and can have two additional zeros of $k_2(t)$ is large enough. Since the polynomials $P_3(N,k_0)$ and $P_3(N,0)$ differ only by a downwards shift by k_0, one finds the following.

(a) If one has

$$P_3(N,k_0) < k_0 \tag{10.4.12}$$

for $N>0$, $P_3(N,0)$ has only one non-negative zero for all positive values of N. The system slides dow towards $N=0$ as the irradiation ceases.

(b) If the condition

$$P_3(N_f,k_0) \geq k_0 \tag{10.4.13}$$

is satisfied, $P_3(N_f,0)$ has two positive roots $(N_{2,0},N_{3,0})$ besides $N_{1,0}=0$. If R is in the region above $N_{2,0}$, the system slides down to or climbs up to $N_{3,0}$ after the irradiation has ceased. This situation is obviously the interesting one in the recent case. Whether the region $N>N_{2,0}$ can be reached during irradiation depends on the properties of $P_3(N,k_0)$.

5. Consider first what happens during irradiation assuming that $P_3(N_f,0)$ has two positive roots $(N_{2,0},N_{3,0})$ besides $N_{1,0}=0$ (the interesting case). $P_3(N,k_0)$ has certainly one root since $P_3(N,f)$ becomes eventually negative due to the term $-k_3N^3$.

(a) If k_0 is large enough there is only one root - call it N_3. One has $N_3>N_{3,0}$ and the energy feed - if allowed to continue long enough or for sufficiently many times- drives the system above $N_{2,0}$ and eventually to N_3, which is stable and is reduced only slowly as $k_2(t)$ decreases. When irradiation ceases, the system goes to $N_{2,0}$, which represents a stable situation and only adiabatically approaches to zero as long as the number of roots remains three. After this N goes rapidly to zero.

(b) If k_0 is small enough one has one or three roots- let the three roots be $N_1 < N_2 < N_3$. N_1 corresponds to a stable situation in which the linear term has driven dN/dt to zero. One ends up to this situation either from $N \leq N_2$ for three roots and always if one has only one root. Only N_1 is achievable by starting from $N(t=0) = 0$ or from $N(t_f)$ achievable during irradiation period. Since the graphs of $P_3(N, k_0)$ and $P_3(N, 0)$ differ only by a shift, it is clear that one has $N_1 < N_{2,0}$ so that the system rapidly slides down to $N = 0$.

6. The conclusion is that the desired situation can be achieved only if $k_2(t)$ is so large that $P_3(N, k_0) > k_0$ holds true at the maximum of $P_3(N, k_0)$ (for $N > 0$) and k_0 is so large that $P_3(N, k_0)$ has only single root. This means that the minimum of $P_3(N, k_0)$ is positive. The extrema $N_\pm$ of $P_3(N, k_0)$ correspond to the vanishing of $dP_3(N, k_0)/dN$ so that one has

$$\begin{aligned} N_\pm &= \frac{k_2}{3k_3} \pm \sqrt{(\frac{k_2}{3k_3})^2 - \frac{k_1}{3k_3}} \ , \\ (\frac{k_2}{3k_3})^2 - \frac{k_1}{3k_3} &\geq 0 \ , \end{aligned} \tag{10.4.14}$$

The conditions for self-sustainment boil down to the equations

$$\begin{aligned} P_3(N_+, 0) &> 0 \ , \\ P_3(N_-, k_0) &> 0 \quad . \end{aligned} \tag{10.4.15}$$

Self-sustaining situation continues as long as $k_2(t)$ is so large that one has 3 roots for $P_3(N, 0)$. For small enough $k_2(t)$ the two roots disappear and the system slides rapidly to $N = 0$. **Fig. ??** illustrates these conditions graphically.

10.4.3 A General Model For The Hologram Substrate

The following model for the hologram substrate is based on the earlier vision about the role of Bose-Einstein condensates of Cooper pairs and bosonic ions in TGD inspired quantum biology.

1. DNA replica trajectory should define the analog of the photosensitive substrate so that the scaled up wave length defining its thickness should be of order 1 cm. The TGD inspired model for the effects of ELF em fields on vertebrate brain [K35] leads to the proposal that Bose-Einstein condensates of various biologically important ions and of Cooper pairs of electrons in the magnetic field associated with the flux quantum define a key element of biological information processing.

   The natural guess is that this process involves in an essential manner the formation of holograms by a radiation generating cyclotron transitions and in this manner affecting the reflective properties of the hologram substrate determined by the rates of elastic scattering. If the flux quanta are flux tubes, one has photo-sensitive tubes instead of photosensitive plates and only the vertical component of the photon momentum is conserved in the scattering and reflected photons can have any direction in the plane orthogonal to the flux tube so that the reflected radiation indeed reaches camera. The properties of the hologram seem to be consistent with the prediction that the information carried by it is only about the vertical and preferred horizontal direction.

2. Cyclotron energies E_c are proportional to $\hbar eB/m$ so that they increase with Planck constant and are inversely proportional the mass of the charged particle. This selects the Cooper pairs of electrons as a unique candidate for the Bose-Einstein condensate. TGD assigns to elementary particles macroscopic time scales as fundamental time scales and in the case of

electron this time scale is.1 seconds which corresponds to 10 Hz fundamental biorhythm. Also for this reason Bose-Einstein condensate of Cooper pairs of electrons defines a natural candidate for the hologram substrate.

3. Cyclotron transitions induced by the incoming dark photons should in the recent case have frequency of order 30 GHz if $\lambda_d \sim 1$ cm is assumed for the dark variant of red light. In the case of electron the magnetic field .2 Gauss (this is the value of endogenous magnetic field deducible from the effects of ELF em fields on vertebrate brain [K35], [L3]) corresponds to frequency of about 6×10^5 Hz so that a magnetic field of order .1 Tesla would give rise to a cyclotron frequency of order 30 GHz. The corresponding magnetic length is $L_B = \sqrt{\hbar/eB}$, which for ordinary value of Planck constant is 4.7×10 nm (note that 10 nm corresponds to cell membrane thickness and thickness of chromosomes). For $r = 15 \times 10^3$ the magnetic length would correspond to 5.8 μm length scale to be compared with the size scale 6 μm of cell nucleus. If one requires the quantization of magnetic flux in multiples of $\hbar$ this field corresponds flux tube with thickness of order 6 μm. Therefore there might be a connection with the size of nucleus and the quantization of magnetic flux meaning that the thickness of the DNA replica trajectory reflects the basic cellular length scales.

4. The cyclotron states of Cooper pairs are harmonic oscillator states in the radial direction of flux tube and eigen states of angular momentum and momentum in the direction of the flux tube labelled by (n, m, k). The integer n is harmonic oscillator quantum number. m and k characterize the projections of angular momentum and momentum in the direction of the flux tube. m is integer and also k is quantized from periodic boundary conditions for the flux tube.

5. The hologram would be generated when the incoming dark photons excite Cooper pairs from the lowest energy eigenstate with oscillator quantum number $n = 0$ to the first eigenstate with $n = 1$ and in this manner affect the reflection properties of the system. The life-time of the hologram is determined by the rate at which the system decays back to the ground state so that one would have dynamical rather than static hologram which is of course what biological system needs.

6. The reflection from the hologram corresponds to an elastic scattering in which the Cooper pair condensate receives momentum but its energy is not affected. Elasticity means that the transition does not affect the energy of the Cooper pair which is the sum

$$E_{n,m,k} = n\hbar\omega + \frac{\hbar^2 k^2}{2m}$$

of the cyclotron energy and kinetic energy of free motion in the direction of the flux tube. If the longitudinal momentum k vanishes as the formation mechanism of the hologram strongly suggests, the value of n remains unchanged but the value of angular momentum projection m in the direction of flux tube can change in elastic scattering. The scattering takes place coherently so that the rate is proportional to N^2, N the number of Cooper pairs. The rate of these transitions is affected when a position dependent portion of the Cooper pairs of the Bose-Einstein condensate is in higher energy state. Therefore the transmittance depends on the point of hologram and the change is in the lowest approximation proportional to the intensity $|A + A_R|^2$ of the incoming dark light as in the case of the ordinary hologram.

10.4.4 Is The Lifetime Of The Hologram Long Enough?

The lower bound for the lifetime of the physical realization of the hologram must be measured in seconds from the results of method II. The lifetime can be also longer since the fading of the physical hologram after the irradiation has ceased can be due do the decay of the reference bream. This means a killer test for the model since the decay rate of the hologram is easy to estimate. The decay rate of hologram can be estimated from the decay rate of excited cyclotron state and the calculation reduces to standard first order perturbation theory for interacting system of charged particles and electromagnetic field which can be found in text books [B30].

1. The lifetime of the hologram can be estimated as the life-time of the excited state. The excited state decays by a spontaneous emission of photons. The lifetime can be estimated by using standard perturbation theory for the interaction of radiation fields and electrons with a scaled up value of Planck constant. Electrons form cyclotron states at flux tubes characterized by three quantum numbers: the harmonic oscillator quantum number $n = 0, 1, 2..$, the angular momentum projection m in the direction of flux tube, and the momentum of electron in the direction of flux tube.

   The interaction Hamiltonian is obtained by the minimal coupling prescription by adding to the vector potential associated with the static magnetic field of the flux tube time dependent radiation part. This means the replacement

$$\mathbf{A} \quad = \quad \mathbf{A}_{flux} \rightarrow \mathbf{A}_{flux} + \mathbf{A}_{rad} \tag{10.4.16}$$

   of the vector potential of the static magnetic field determining cyclotron energy spectrum in the magnetic field parallel to the flux tube with a vector potential containing also the vector potential of the second quantized radiation field.

2. This replacement affects the Hamiltonian of the system in the following manner

$$\begin{aligned} H_0 &= \frac{1}{2m}(\mathbf{p} - Ze\mathbf{A}_{flux}) \cdot (\mathbf{p} - Ze(\mathbf{A}_{flux}) \rightarrow H \ , \\ H &\equiv H_0 + H_{int} = \frac{1}{2m}(\mathbf{p} - Ze(\mathbf{A}_{flux} + \mathbf{A}_{rad})) \cdot (\mathbf{p} - Ze(\mathbf{A}_{flux} + \mathbf{A}_{rad})) \ , \\ H_{int} &= -\frac{1}{2m}\left[(Ze\mathbf{p} \cdot \mathbf{A}_{rad} + \mathbf{A}_{rad} \cdot \mathbf{p}) + Z^2e^2\mathbf{A}_{flux} \cdot \mathbf{A}_{rad} + Z^2e^2\mathbf{A}_{rad} \cdot \mathbf{A}_{rad}\right] \end{aligned} \tag{10.4.17}$$

   $Z = 2$ is the charge of the electron Cooper pair and $m = 2m_e$ is its mass. In Coulomb gauge one has

$$\nabla \cdot \mathbf{A}_{rad} = 0$$

   and the the interaction Hamiltonian H_{int} determining the transition rate reduces in the lowest order to

$$\begin{aligned} H_{int} &= -\frac{Ze}{m}\mathbf{A}_{rad} \cdot \mathbf{p} \ , \\ \mathbf{p} &\equiv \frac{\hbar}{i}\nabla \ . \end{aligned} \tag{10.4.18}$$

3. If the radiation generating hologram is in horizontal plane, cyclotron states have vanishing momentum quantum number in the vertical direction. Therefore also the emitted radiation has momentum and polarization in this plane. In principle this could be tested by using polarization sensitive camera.

4. The rate for the return to the ground state is calculable by using standard time dependent perturbation theory the result of which can be expressed as a formula for the total transition rate to the ground state

$$\Gamma \quad = \quad \frac{mE}{(2\pi)^2\hbar^4}\int d\Omega |\langle f, \hbar\mathbf{k}|H_{int}|i\rangle|^2 \ . \tag{10.4.19}$$

   Here integration is over the solid angle that is over the momentum directions of the emitted photon. Here m is the mass of Cooper pair (two times electron mass) and E is photon energy (in eV range for visible photons).

5. The matrix element $|\langle f, \hbar\mathbf{k}|H_{int}|i\rangle$ of the interaction Hamiltonian is expressible in the lowest order approximation as

$$\langle f, \hbar\mathbf{k}|H_{int}|i\rangle \quad = \quad -i\frac{\hbar Ze}{m\sqrt{\omega}}\int \overline{\Psi}_{n_f,m_f,k_f}e^{i\mathbf{k}\cdot\mathbf{r}}\mathbf{e}\cdot\nabla\Psi_{n_i,m_i,k_i}dV \quad . \tag{10.4.20}$$

$\mathbf{e}$ denotes the polarization vector of the photon and $\mathbf{k}$ its wave vector. The integration is over the flux tube volume.

In dipole approximation one can expand the plane wave to the first non-trivial order. If one assumes that the transitions responsible for the decay of the hologram correspond to the transitions $(n_i, m_i, 0) = (1, \pm 1, 0) \to (n_f, m_f, 0) = (0, 0, 0)$, one has

$$\langle f, \hbar\mathbf{k}|H_{int}|i\rangle \quad \simeq \quad \frac{\hbar Ze}{m\sqrt{\omega}}\int \overline{\Psi}_{0,0,0}\mathbf{e}\cdot\nabla\Psi_{1,\pm 1,0}dV \quad . \tag{10.4.21}$$

The result does not depend on photon energy at all. Angular momentum conservation requires that the angular momentum projection of the state in the direction of the flux tube changes by one unit corresponding to the spin of the photon. This allows to transform the matrix element to

$$\langle f, \hbar\mathbf{k}|H_{int}|i\rangle \quad \simeq \quad \pm i\frac{\hbar Ze}{m\sqrt{\omega}}\int \overline{\Psi}_{0,0,0}\mathbf{e}\times\mathbf{e}_\rho\frac{1}{\rho}\Psi_{1,\pm 1,0}dV \quad . \tag{10.4.22}$$

Here $\mathbf{e}_\rho$ denote the unit vector $(x\mathbf{i} + y\mathbf{j})/\rho$ in radial direction. The magnitude of the matrix element is of order

$$\langle H_{int}\rangle \quad \sim \quad (\hbar Ze/m\sqrt{\omega}) \times \langle\frac{1}{\rho}\rangle \sim \frac{\hbar e}{mR\sqrt{\omega}} \quad , \tag{10.4.23}$$

where R is the radius of the flux tube.

6. The overall rate for the decay of the hologram has the order of magnitude

$$\Gamma \quad \sim \quad \frac{4\pi^2\alpha}{r}\frac{\hbar_0}{R^2 m_e} \sim \frac{4\pi^2\alpha}{r^3}\frac{\hbar_0}{\lambda^2 m_e} \quad , \quad r = \frac{\hbar}{\hbar_0} \quad . \tag{10.4.24}$$

Here λ denotes the wave length of ordinary visible photon. Formally the rate scales as $1/r$ as the naïve dimensional estimate suggests but $R \simeq r\lambda$ brings in an additional $1/r^2$ reduction factor so that $1/r^3$ over-all dependence results. For $r = \hbar/\hbar_0 \sim 10^4$ the order of magnitude for the decay rate is for visible light $\Gamma \sim 10^{-5}$ s^{-1}, which is consistent with the observed slow rate of decay. As noticed, the fading of the hologram in experiment two could be due to the decay of the reference beam rather than the decay of hologram. Maybe also this could be tested. In any case, the model survives the first killer test.

10.4.5 The Amplitude For The Elastic Scattering From Hologram

The rate for the elastic scattering of photons of the reference beam from the hologram substrate defines the intensity of the hologram image and should be high enough.

1. This process involves two photons. The term

$$H_{int}^{2)} = \frac{e^2}{2m}\mathbf{A}_{rad}\cdot\mathbf{A}_{rad} \tag{10.4.25}$$

   in H_{int} makes this transition possible in the first order of perturbation theory.

2. One can worry about second order perturbation theoretic contribution to the rate which is also of order e^2. The generalization of the Golden Rule is obtained by the replacement

$$\langle f|H_{int}|i\rangle \quad\rightarrow\quad \langle f|H_{int}|i\rangle + \sum_m \frac{\langle f|H_{int}|m\rangle\langle m|H_{int}|i\rangle}{E_n - E_0 + i\eta\hbar} \quad , \quad \eta\rightarrow 0_+ \quad . \tag{10.4.26}$$

   The sum over m denotes sum over intermediate states. In the second order of perturbation theory the scattering can be thought of as taking place via intermediate states of Cooper pairs decaying back to the original state via the emission of photon. In the following rough estimate only the lowest ordinary contribution is taken into account.

3. In this approximation the amplitude for elastic scattering responsible for the hologram formation with $(n_i, m_i, k_i) = (n_f, m_f, k_f)$ and $\omega_i = \omega_f = \omega$ with the amplitude is apart from numerical factor of order unity given by

$$\langle f, \hbar\mathbf{k}|H_{int}|i\rangle \quad = \quad \frac{e^2\hbar^{1/2}\mathbf{e}_i\cdot\mathbf{e}_f\omega_i}{m\sqrt{\omega_f}}\int \overline{\Psi}_{n_i,m_i,0}e^{i(\mathbf{k}_i-\mathbf{k}_f)\cdot\mathbf{r}}\Psi_{n_i,m_i,0}dV \quad . \tag{10.4.27}$$

   In the lowest order approximation plane wave factor can be neglected. The order of magnitude for rate differs by a factor $4\pi\alpha(\omega R)^2$ from the matrix element for the decay of the hologram. For $R\sim\lambda_d$ the rates are of the same order. This rate corresponds to single photon case. In the case of many-photon state defined by the reference beam the rate is amplified by a factor N^2, where N is the number of photons in the reference beam.

10.5 Appendix: Details About Methods I And II

Two methods represent the two schemes developed for our experimental purposes. In order to adduce and visualize DNA wave replicas, the following is to be performed: by means of timing relay (**Fig.** 10.13, position #3) in varied combinations the operator switches on the required emitters BS (UV-B, which is incandescent lamp in blue spectrum, glass type- **Fig. 10.13**, position #5), a matrix with red and infrared diodes (**Fig. 10.13**, position #8) and germicidal mercurial lamp/bulb or lamp Compact electronic CEST26E27 Black (UV-C, **Fig. 10.13**, position #6), or BS (UV-B) and MXT-90 (cold catode – **Fig. 10.13**, position #4).

1. Method I.
   Dehydrated/dry DNA sample from bull's spleen - about 100 milligrams in a sealed plastic conical test tube, which is 4 centimeters long and 0.9 cm in its upper end; or 3 milliliters of DNA water solution, 1mg/ml) are placed in the effective zone of the emitters (1mm-50cm from the light emitters) and then the emitters are activated. The progression of the experiment was filmed using Fuji 24-27 DIN film. Oscillograph is in operation during the experiment and is to register and record the electromagnetic fields/frequencies within the

zone of the experiment; averaged normal electromagnetic background noise from within the premises is recorded, defined by the behavior of sinusoid in the oscillograph. Further, by means of the timing relay the emitter UV-C is turned off 10 minutes later. The camera captures an emergence of unique dynamic wave structures – multi-replicated DNA replicas and of the surrounding objects invisible to the naked eye, yet perceivable by the camera and fixed on the film. These are directly related to the photonic influences effected by the emitters on the DNA samples. In other words, multiplication of a number of reflection of DNA samples occurs and is redistributed in space on complex trajectory patterns (the first method) and on horizontal patterns (the second method), including mapping of the objects responsible for exciting the DNA samples.

2. Method II
The second method to obtain and visualize DNA wave replicas involves the following: dehydrated/dry DNA sample, 100 milligrams is placed in an open mode into a holder made of aluminum foil. With intervals of 2-3 seconds the BS (UV-B) lamp, Compact Electronic CEST26E27 Black lamp and apparatus Duna-M are turned on and off. Photographs are taken 5 minutes later. By this method the DNA replicas and of close objects are registered and they are propagating strictly to the right hand side. With external mechanical interference (a touch) with the DNA samples the distribution vector alters to the opposite – that is the DNA replicas begin propagating to the left hand side and than 5-8 seconds after the mechanical interference the replicas disappear or are not perceived by the present equipment4 or the utilized film, regardless of the equipment still being in an activated state.

10.6 Figures

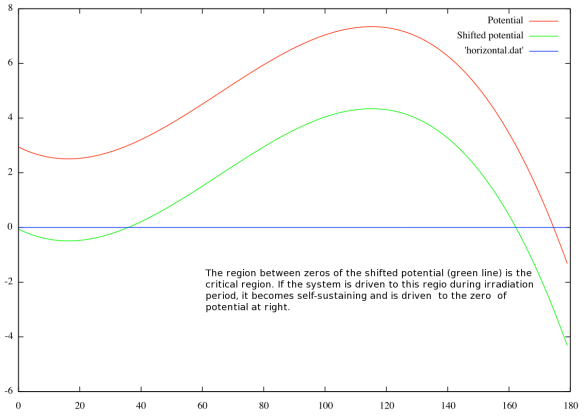

Figure 10.1: Illustrations of a potential $V(x) = P_3(x) = a - bx + cx^2 - dx^3$ and shifted potential $V(x) - a$ allowing self-sustainment. Note that the full potential allows only single zero and shifted potential two zeros. If the system ends up to the region between the two zeros of the shifted potential during irradiation, it ends up to the rightmost zero after the irradiation period. When the value of the parameter c decreases adiabatically below certain critical value, the value of x (having interpretation as photon number) goes rapidly to zero.

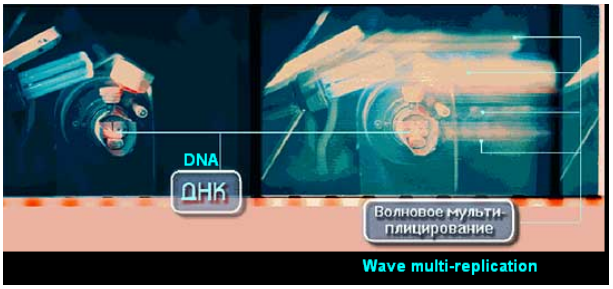

Figure 10.2: The left hand side figure is from [K17] and represents the replica images of the instruments and the image interpreted by experimenters as a replica image of DNA sample (method II). The white cable like structures to the left from DNA sample have interpretation as phantom DNA image.

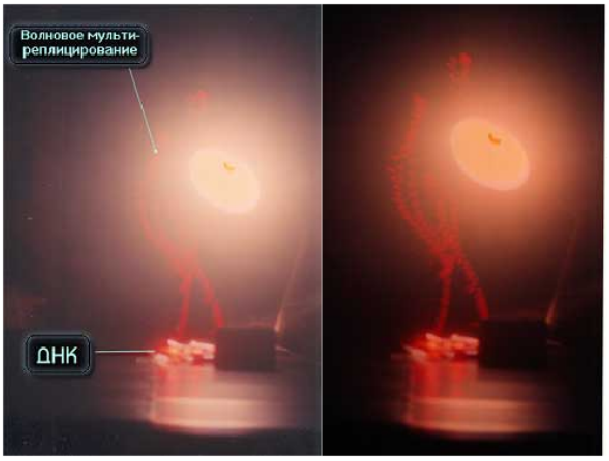

Figure 10.3: The picture shows the discrete replica like structure of the band like image obtained by method I and interpreted by experimenters as replica image of DNA sample.To the left image is the original image and to the right the contrasted one.

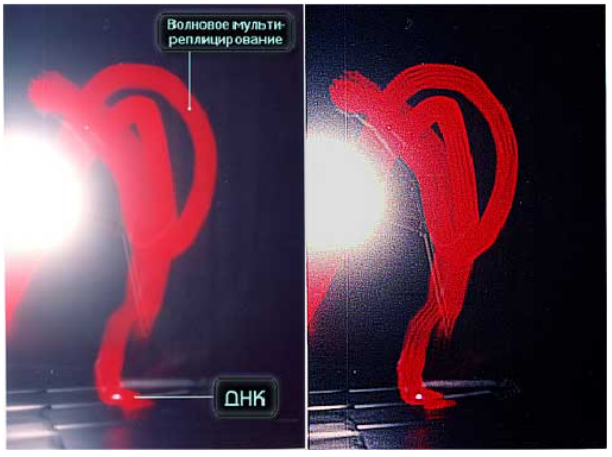

Figure 10.4: Spatial structure of DNA wave replicas obtained by method I. The picture reveals the 5-fold fine structure of the tube like image interpreted by experimenters as replica image of DNA sample. The 5-fold character probably correspond to five red LEDs above the sample. To the left image is the original image and to the right the contrasted one.

Figure 10.5: Long living DNA wave replica from the experiment in **Fig.** 3 (referred to as phantom image as opposed to the image seen during irradiation) subsequent to switching off of the initiating electromagnetic fields/frequencies sources.

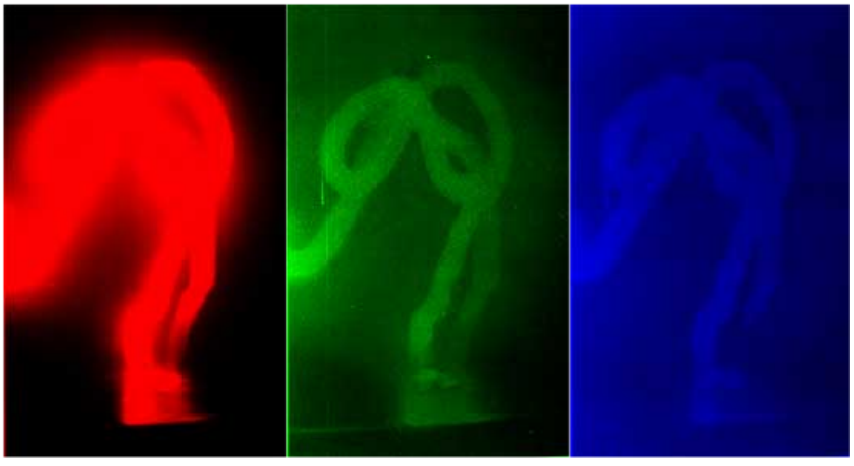

Figure 10.6: Distribution of the brightness values per RGB color model, Red, Green, Blue of the phantom DNA image of previous figure. The green image gives especially clear picture about the structure of phanton DNA image.

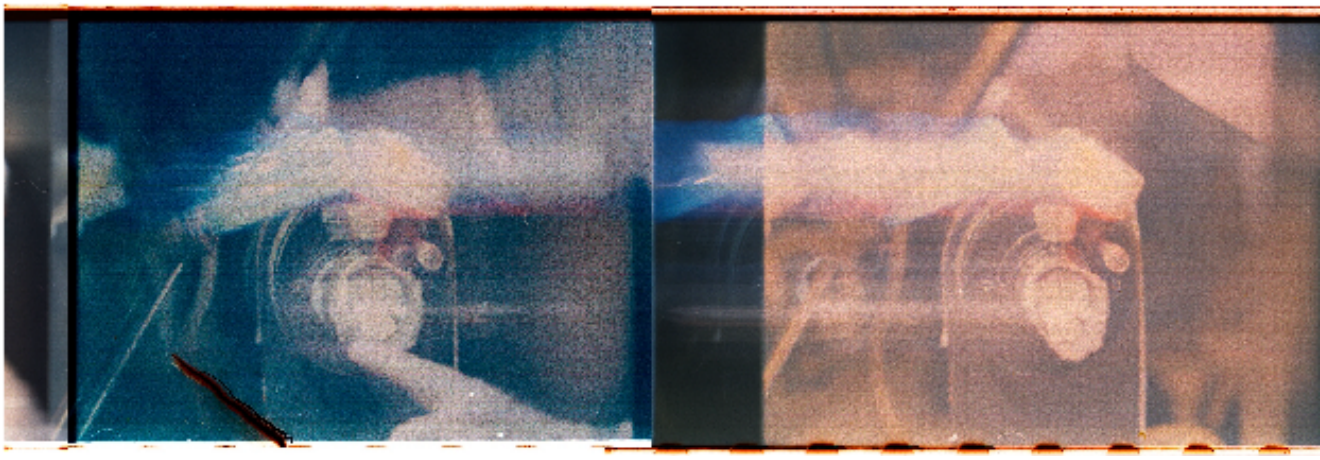

Figure 10.7: a) The moment of mechanical external interference (touch, which could have also biological effect) with DNA sample. The second method of elicitation of DNA wave replicas. b) Shift to the left of the wave replicas immediately after the interference. It is also commonly noticed that there is a sharp distinction of the shot from others by brightness and color scheme, which is unrelated to the working of the camera.

Figure 10.8: Disappearance of DNA wave replica formation effect after 5-8 seconds following the interference with the DNA sample (touch, see previous figure) while the entire equipment initializing the replicas is still on.

Figure 10.9: One of the modified experiments, shown in **Fig.** 5 (old DNA sample replaced by new). Refer to the shots # 3 and #4 above. The shot #4 reveals replicas of the "Duna-M" diodes, shifting to the right side. Note the appearance of replicas of perforation and exposed parts of the film close to diodes.

Figure 10.10: Shots #11 and #12 above. It is to be mentioned that from shot #1 until shot #11 the Duna-M diodes wave replicas are absent, however appearing again in the shot #12.

Figure 10.11: Shots #13 and #14 above. In the #13 we can distinguish wave replicas of the Duna-M diodes with the commonly observed intrusion in into the unexpected space between the shots. The shot #14 does not capture the wave replicas of the diodes and they disappear.

Figure 10.12: Shots #23 and #24 above. From shot #14 until #22 replicas disappear, they are dimly captured in the shots #23 and #24.

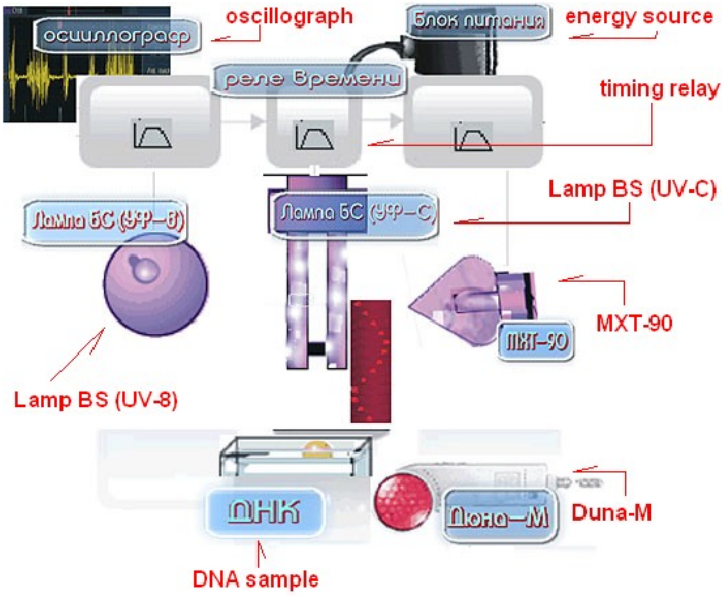

Figure 10.13: Schematic representation of the parts of the experimental apparatus

Chapter 11

Quantum Model for Remote Replication

11.1 Introduction

The idea about remote replication, transcription and translation of genes in terms of electromagnetic field patterns is very attractive and would be in accordance with the wave DNA vision. This requires a coding of DNA nucleotides. I have proposed several codings of this kind.

1. In DNA as topological quantum computer model [K3] quark and anti-quark at the ends of a flux tube connecting DNA nucleotide to a lipid of the nuclear or cell membrane takes care of the coding. Also sequences of dark nucleons giving rise to dark nuclei realize the analogs of DNA, RNA, tRNA, and amino-acids as well as vertebrate genetic code [K106], [K47]. Dark nucleons sequences could correspond to the phantom DNA discovered by Gariaev's group [I87].

2. Quantum antenna hypothesis represents one of the oldest ideas of TGD inspired quantum biology [K68]: molecules would act like quantum antennas. Frequency coding would be very natural for groups of molecules participating in the same reaction: the flux tubes connecting the molecules would carry the radiation inducing resonant antenna interaction and phase transitions reducing Planck constant would bring the reacting molecules near to each other. Magnetic flux tubes connecting the molecules would be essential element of the mechanism. Remote replication would represent an example about a situation in which $\hbar$ changing phase transition does not take place. If one wants coding of individual molecules -such as DNA nucleotides- by frequency in turned coded by the value of $\hbar$ for given photon energy ($E = hf$), one is forced to make ad hoc assumptions and it is difficult to find any plausible scenario. Quantum antenna mechanism could make possible remote replication for which the findings of Montagnier's group as well as remote transcription for which the work of Gariaev's group gives some evidence.

3. One can consider also a coding by field patterns. In fact, the quark and antiquark at the ends of the flux tube generate a color magnetic field coding for the quark pair since the classical color field depends on the color of the quark and its antiquark. Gariaev's group has proposed that the change of polarization direction could provide a possible mechanism of coding of DNA sequences to radiation patterns [I86]. The proposal is discussed from TGD point of view in [K104]. The mechanism changing the polarization direction should reduce to different propagation velocities for the two circular polarizations. The other polarization should act more strongly with the DNA related structures and this should cause the slowing down of propagation since it would correspond to sequence of absorptions and emissions. The constraint that this occurs coherently for DNAs and codes the DNA sequence is very powerful condition. It is however difficult to imagine how this mechanism alone could give rise to remote replication of DNA or similar processes: the coding from radiation pattern to DNA sequences is the bottle neck. Therefore this mechanism will not be discussed in the following.

11.1.1 The original model of remote replication

In the sequel a model for the coding of DNA in terms of radiation patterns is discussed. There are three experimental guidelines: the phantom DNA [I87] identified as dark nucleon sequences in TGD framework and the evidence for remote activation of DNA transcription [I86] - both discovered by Gariaev's group - are assumed as the first two key elements of the model. The remote replication of DNA suggested by the experimental findings of Montagnier's group serves as a further guideline in the development of the model. Also the results of the latest experiment of Gariaev's group in many respects similar to that of Montagnier's experiment but differing in certain crucial aspects from it are used as input.

Polymerase chain reaction (PCR) (see `http://tinyurl.com/ybv6mn5l`) is the technique used in the experiments of Montagnier's group [I53] and later in somewhat modified experiment by Gariaev's group involving irradiation of the second test tube by laser light. DNA polymerase catalyzes the formation of DNA from existing DNA sequences serving as a template. Since the catalytic interaction of DNA polymerase takes place with already existing DNA sequence, the only possibility is that first some conjugate DNA sequences are generated by remote replication after which DNA polymerase uses these sequences as templates to amplify them to original DNA sequences. Whether the product consists of original DNA or its conjugate can be tested.

The model inspires the proposal that the magnetic body of a polar molecule codes for it using dark nucleon sequences assignable to the hydrogen bonds between the molecule and surrounding ordered water layer. Quantum antenna mechanism would allow the immune system to modify itself by developing ordinary DNA coding for amino-acids attaching to and thus "catching" the polar molecule. The mechanism could be behind water memory and homeopathic healing. The most general option is that every polar molecule in living matter would be accompanied by a dark nucleon sequence or several of them (as in the case of amino-acids) serving as its name. This would also associate a unique dark nucleon sequence also with the magnetic body of DNA so that DNA-dark DNA association would be automatic. Same applies to mRNA and tRNA and amino-acids.

Remark: The first part of the chapter is essentially the article published together with Peter Gariaev in DNA Decipher journal [L99]. The considerations described below reflect the more recent views about remote replication.

11.1.2 Further developments of the model for remote replication

A more detailed model for the remote replication inspired by the findings of Luc Montangier's group

The findings of Montagnier *et al* [I97] (`http://arxiv.org/abs/1012.5166`) raise the possibility of remote replication of DNA. Montangier's experiment involves two chambers A and B. A contained water and genes and B water and DNA nucleotides. There were channels between the chambers but so thin that DNA could not get through. Also an em field with 7 Hz frequency was present. Same genes as in A appeared also in B. As if remote replication of genes in A had happened in B. I have written articles about Montagnier's findings [L16, L21]. Gariaev has reported a similar phenomenon already before Montagnier *et al*: we wrote together with Peter Gariaeb an article discussing the TGD based model for the finding [L99].

The model for remote replication discussed below is a modification of a model developed earlier together with Peter Gariaev on basis of his findings and involves the following basic building bricks.

1. In TGD inspired vision about quantum biology relying on the notion of magnetic body (MB) carrying dark matter as phases of ordinary matter with effective Planck constant $h_{eff} = n \times h_0$ one ends up with the notion of dark DNA realized as sequences of dark protons and to the surprising finding that dark proton triplets realize vertebrate genetic code and basic biomolecules DNA,RNA,tRNA, and amino-acids [L28, L41].

2. Second realization of the genetic code is using dark photon 3-chords [L24, L25, L20]. The allowed 3-chords of icosahedral code realized as a Hamiltonian cycle define a harmony with 20 chords and having as a symmetry subgroup Z_6, Z_4 or Z_2 of icosahedral geometry. The harmony is fixed by a Hamiltonian cycle of icosahedron defining a 12-note scale. Tetrahedral

harmony has 4 chords and is unique. The symmetry group acts on the frequencies of the chord as a scaling and this is realized if the scale is obtained by quint cycle using octave equivalence.

The fusion of 3 icosahedral codes with different symmetries with tetrahedral code gives rise to bio-harmony with 64 chords. Genetic codons are identified as allowed 3-chords and amino-acids as orbits of codons. The number of codons at the orbit of given codon would correspond to the number of DNA codons coding for amino-acid and the predicted numbers are correct for the vertebrate code under rather general assumption although also the variants of the code can be understood as being due to the failure of exact mimicry of dark photon code by the chemical realization. The identification of bio-photons as decay products of dark cyclotron photons with large value of h_{eff} having universal energy spectrum due to the condition $h_{eff} = h_{gr}$ [K72].

A model for the radiative coding of DNA creating 1-1 correlation between ordinary and dark DNA codons and between two dark DNA codons.

3. TGD explanation [L22] for the fourth phase of water discovered by Pollack [L22, I128] and characterized by negatively charged exclusion zones EZs generated by radiation.

Galois confinement and (remote) replication in codon-wise way

TGD predicts two dark variants of genetic code realized as dark codons (DDNAs) identified either as dark proton triplets or dark photon 3-chords. The objection against dark photon 3-chords (3-photon states) is that the simultaneous emission of 3 dark photons is extremely non-probable. The proposed solution of the problem is that dark photons carry a number theoretic color associated with a Z_3 sub-group of the Galois group. Number theoretic color confinement would imply that only 3-chords can appear as asymptotic states analogous to baryons as 3-quark states. If also the dark protons form a number-theoretic color triplet, dark codons must consist of 3 protons and therefore also ordinary codons would have 3 letters.

The findings of Gariaev's group and Montagnier *et al* suggest the possibility or remote replication of DNA. The fact that dark codons do not decompose into letters like chemical codons poses strong constraints on the replication and transcription if one assumes DDNA-DNA-pairing. These constraints strongly suggest that the nucleotides in the water environment of DNA are not actually free but form loosely bound triplets representing codons bound with DDNAs. Replication is predicted to occur in a codon-wise way: this has been observed to be possible for RNA. It might be that the loose nature of exotic DNA codons allows this to occur quite generally.

Remote replication in this framework reduces to ordinary replication in TGD sense if also dark genes are present and formed by attaching flux tubes characterizing dark codons to a long flux tube associated with a gene. Remote replication requires that the portion of dark gene accompanying the ordinary gene is transferred from chamber A to chamber B in the experiment of Montagnier.

Codon-wise replication of RNA in lab

It is possible to replicate unfolded RNA strands in lab by using enzymes known as ribozymes, which are RNA counterparts of enzymes, which are amino acid sequences. In the presence of folding the replication is however impossible. Since ribozymes are in general folded, they cannot thus catalyze their own replication in this way. However, it has been discovered that the replication using RNA triplets - genetic codons - as a basic unit can be carried out in lab even for the folded RNA strands and with a rather low error rate. Also the ribozyme involved can thus replicate in a codon-wise way. For units longer than 3 nucleotides the replication becomes prone to errors.

The TGD based model for the findings relies on the vision that there are several realizations of the counterparts of DNA, RNA, tRNA, and amino-acids and of the genetic code so that chemical code is only one particular realization. For the dark realization in terms of entangled dark proton triplets one cannot analyze the codons to triplets of ordered letters so that codon is the smallest unit. This motivates the question whether RNA replication during the proposed RNA era happened in a codon-wise way and relied on pre-tRNA in which amino-acid catalyzed

the addition of RNA of tRNA to RNA sequence. The second possibility would be that replication occurs for dark codons basically so that ordinary letter-wise replication for DNA would actually occur codon-wise. The nucleotides in the water environment of genes would combine with scaled up dark codons to form "loose" variants of ordinary codons having no valence bonds between the nucleotides.

The crucial evolutionary step would have been analogous to the emergence of written language in which words decomposed into letters meaning a transition from RNA era to DNA era and DNA replication and transcription in a letter-wise fashion. At this step DNA and RNA polymerase and DNA helicase emerged. This picture is discussed from the point of view of the realization of the code in terms of 3-chords formed from dark photons. The 12-note scale forming the basis of the model of bio-harmony based on 64 chord harmony emerges naturally.

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` [L19].

11.2 The Findings That One Should Understand

It is good to start by summarizing the experimental findings that the model should explain.

1. One should be able to identify phantom DNA [I87]. This identification explains the findings about phantom DNA if ordinary and dark DNA have common resonance frequencies and therefore behave like resonantly interacting quantum antennae.

2. The earlier findings of Gariaev's group suggesting remote gene expression [I86], which becomes also possible if the DNAs of the sender can activate the DNA of the receiver by radiation. Direct activation could be based on electromagnetic signal between DNA of the sender and ordinary conjugate DNA of the receiver. Scattering from ordinary and possibly also phantom DNA and would generate this kind of signal. The challenge is to explain why the activation obeys genetic code in the sense that a given DNA sequence activates only similar DNA sequence.

3. The claim of Montagnier's team [I96, I97] is that the radiation generated by DNA affects water in such a way that it behaves as if it contained the actual DNA. A brief summary of experiment of Montagnier and collaborators is in order.

   (a) Two test tubes containing 100 bases long DNA fragments were studied. Both tubes were subjected to 7 Hz electromagnetic radiation. Earth's magnetic field was eliminated to prevent its possible interference (the cyclotron frequencies of Earth's magnetic field are in EEG range and one of the family secrets of biology and neuroscience since seventies is that cyclotron frequencies in magnetic fields have biological effects on vertebrate brain). The frequencies around 7 Hz correspond to cyclotron frequencies of some biologically important ions in the endogenous magnetic field of.2 Tesla explaining the findings. This field is 2/5 of the nominal value of the Earth's magnetic field.

   (b) What makes the situation so irritating for skeptics who have been laughing for decades for homeopathy and water memory is that the repeated dilution process used for the homeopathic remedies was applied to DNA in the recent case. The solution containing no detectable amounts DNA (dilution factor was 10^{-12}) was placed in second test tube whereas the first test tube contained 100 bases long DNA in the original concentration.

   (c) After 16 to 18 hours both tubes were subjected to polymerase chain reaction (PCR), which builds DNA from its basic building bricks using DNA polymerase enzyme. What is so irritating from the point of view of skeptic was that DNA was generated also in the test tube containing the highly diluted water. Water in presence of second test tube seems to be able to cheat the polymerase by mimicking the presence of the actual DNA serving in the usual situation as a template for builing copies of DNA. One could also speak about the analog quantum teleportation. Note that the presence of both test tubes - and therefore some kind of communication between the samples - is absolutely esential for the process to take place: repeated dilution is not enough.

4. Peter Gariaev's team has carried out an analogous experiment recently in which one has two test tubes containing water. Tube A contained DNA fragments and tube B contained only water and DNA nucleotides plus DNA polymerase - just as as in Montagnier's experiment. The analog of the homeopathic procedure was not however applied to tube B. The experiments use a drop of DNA in water in gamma concentration in tube A. This DNA (with length of 600 base pairs) was scanned by laser radiation from helium-neon laser. The scattered radiation having a wide spectrum of frequencies down to kHz frequencies was applied on tube B at distance of 3 m in refrigerator (+4 Celsius) containing distilled water solution of DNA nucleotides and DNA polymerase inducing polymer chain reaction PCR amplifying DNA template if present. The generation of DNA sequences in tube B with the same mass distribution as in tube A by polymer chain reaction (PCR) is observed suggesting that the necessary DNA template is generated as a direct copy or conjugate of the original in test tube A by some unknown mechanism. Nucleotide sequences have not been analyzed to see whether they are identical or conjugates of those in tube A.

11.3 The Model Of Remote Replication Consistent With DNA As Topological Quantum Computer Model

The basic assumptions are that the scattered radiation, the flux tubes of the magnetic body of DNA along which the radiation propagates, and quarks and antiquarks at the ends of the flux tubes from system able to serve as a template for the formation of conjugate of ordinary DNA. To understand how remote remote replication could take place, some further assumptions are necessary.

1. The flux tubes emanating from DNA are parallel and condensed at 2-D flux sheet having DNA at is first boundary so that DNA nucleotides can attach to the flux tubes at the second boundary. The attached nucleotides would be along the same line and would form DNA sequence in remote replication process.

2. Quantum antenna interaction takes place between group of molecules participating a given reaction so that they have common antenna frequency as resonance frequency. The frequencies characterize the radiation propagating along magnetic flux tubes connecting the molecules, and could come as sub-harmonics of the frequency of (in the case considered) visible light from the formula

$$E = h_n f, \;\; h_n = nh \;\; , \;\; n = 1, 2, 3, ... \;\; .$$

Here E is the fixed energy of photon. h_n denotes value of Planck constant which in TGD Universe can have infinite number of values coming as multiplies of the ordinary Planck constant h.

For a given photon energy E one obtains harmonics of the basic wavelength

$$\lambda = \frac{c}{f(n)} = n\lambda_0 \;\; .$$

Wave length would correspond to the length of the flux tube proportional to n. DNAs with flux tubes characterized by different values of n would correspond to different levels in the evolutionary hierarchy. In TGD inspired theory of consciousness the value of h_n serves as the measure for the time scale of planned action and memory span and neurons of frontal lobe would represent the highest level in the hierarchy,

3. If resonance frequency is same for all nucleotides, frequency cannot distinguish between DNA nucleotides. In the model of DNA as topological quantum computer the quark (u or d) and antiquark ($\overline{u}$ or $\overline{d}$) at the ends of the flux tube code for A, T, C, G. This model is the simplest one and does not require any additional assumptions about frequency coding. It also allows resonant interaction at several frequencies: the scattering of visible light from DNA indeed produces a wide spectrum of frequencies interpreted in terms of dark variants of visible photons.

One can criticize the assumption that particular quark or antiquark is associated with the flux tube ending at particular nucleotide. At this moment this assumption does not have a convincing dynamical explanation. Presumably this explanation would rely on the minimization of the interaction energy.

4. What is needed is a model explaining why the resonant antenna frequency does not depend on nucleotide: obviously the frequency should relate to something shared by all nucleotides. An energy level associated with sugar-phosphate backbone of DNA is what comes first in mind. A more exotic option is transition involved with quark-antiquark pair. Since electromagnetic field for non-vacuum extremals is accompanied by classical color field, the exchange of gluons between quark and antiquark suggests itself as the quantum antenna interaction distinguishing between nucleotides.

Quantum antenna mechanism is extremely general and flexible and might be a fundamental mechanism of bio-catalysis allowing also communication between visible and dark matter sectors. Antenna mechanism is of course central also in ordinary communications. If the biologically most relevant interactions of biomolecules via quantum antenna mechanism then also water memory and the claimed effects of homeopathically treated water might be understood [K47]. The testing of the dark photon aspect of the hypothesis would require the detection of the dark photons somehow: the decay to a bunch of n ordinary photons with same wavelength is the obvious manner to achieve this.

11.3.1 Identification Of Phantom DNA

The observed residual coherent scattering from a chamber from which ordinary DNA is removed inspired the notion of phantom DNA [I87]. The questions are what phantom DNA is and is it relevant to remote replication of the ordinary DNA.

Phantom DNA observed in the scattering experiments could correspond to dark nucleon sequences realizing vertebrate genetic code with dark nucleons consisting of three quarks representing both DNA, RNA, tRNA, and amino-acids as particular nucleon states [L2, K47]. The resonant interaction between ordinary and dark DNA would explain why light at same frequencies scatters also from dark DNA in phantom DNA experiments. In Montagnier's experiments it could give rise to a positive feedback amplifying the radiation from second sample containing DNA. Water would be living in the sense that it contains "dark DNA" and dark DNA might allow remote transcription to ordinary DNA sequences in presence of ordinary DNA codons (triplets) and vice versa.

Skeptic can of course ask whether one could explain the experimental findings without assuming phantom DNA.

1. In Gariaev's experiments [I87], which inspired the notion of phantom DNA part of DNA could "drop" to parallel space-time sheets and have the same effect on the scattered radiation as the ordinary DNA. This explanation would however require the many-sheeted space-time of TGD - probably equally abominable to skeptic as phantom DNA.

2. In Montagnier's experiment and also in the recent experiment of Gariaev the ordinary DNA contained by water droplet could diffuse to dark space-time sheets and enter from flux tube A to flux tube B along the same magnetic flux tubes as radiation propagates. DNA polymerase would allow to amplify this leaking DNA and produce conjugate DNA. The irradiation of the original DNA would generate the flux sheets serving as a route for the transfer. The killer test is to check whether it is indeed conjugate of the original DNA which is produced. Again many-sheeted space-time is required.

3. For the option based on DNA as topological quantum computer hypothesis discussed above the remote replication would take place via the direct formation of conjugate DNA template and DNA polymerase produces from this copies of the *original* DNA whereas for "trivial" option conjugate DNA is produced. Phantom DNA would not be absolutely necessary. It is however questionable whether the intensity of the radiation is high enough and the resonant interaction with phantom DNA which could give rise to a positive feedback might be needed to amplify the radiation.

11.3.2 Dark DNA And Frequency Coding By Quantum Antenna Mechanism

The remote transcription of dark DNA (phantom DNA) to ordinary DNA and vice versa would have quite far reaching implications for evolution since dark DNA/RNA/tRNA/amino-acids could define a virtual world serving as $R\&D$ lab where new DNAs could be developed and if needed translated to ordinary DNA. The dark DNA could be also transferred through cell membranes without difficulty, in particular to germ cells. Also the genetic transfer between different organisms would become possible. Second possibility is that the magnetic flux tubes mediating the dark photons traverse the cell membranes so that even the transfer of dark nucleons through the cell membrane is un-necessary. The implications for genetic engineering would be obvious.

Could one generalize the quantum antenna mechanism to the interaction between dark nucleons representing DNA triplets as entangled states of three quarks and ordinary DNA codons consisting of three unentangled nucleotides? Could similar mechanism realize genetic code assigning to dark DNA dark variants of RNA, tRNA and amino-acids via the analogs of transcription and translation processes? It seems that frequency coding, which - somewhat disappointingly - did not look natural for remote replication of ordinary DNA, is ideal for these processes so that the original idea of wave DNA would be realized at the level of dark-visible and dark-dark interactions.

The flux tubes would be associated with entire codons -DNA triplets - rather than individual nucleotides. Different DNA triplets do not form interacting groups in the sense that they should be connected by flux tubes. Therefore the simplest possibility would be frequency coding with specific resonance frequency for each DNA triplet. No quarks at the ends of the flux tubes connecting codons are needed.

Remark: : A hierarchy of flux quanta is essential and must distinguish between its levels. Flux tubes associated with nucleotides at flux tubes associated with DNA codons at flux sheets traversing DNA strands.

If one assumes that octaves correspond to the same frequency this would require odd multiples

$$\lambda(n) = (2n+1)\lambda_0 \quad , \quad n = 0, ..., 63$$

of λ_0 so that the longest wavelength would be $127\lambda_0$. In the number theoretic model of the genetic code based on the notion of Combinatorial Hierarchy [K44] codons are indeed labeled by 64 integers in the range $0, ..., 127 = 2^7 - 1$. These integers are however not assumed to be odd. One can also consider the possibility that the frequencies are coded by the value of Planck constant and this option leads to an interpretation of the earlier proposed realization of divisor code [K106] to be discussed later on.

Support for this option comes from the phenomenon of phantom DNA demonstrating that resonant scattering of light from DNA and dark DNA occurs for the same frequencies.

Can one imagine remote transcription of dark DNA to ordinary DNA using *only nucleotides* as building bricks? This process would require coupling of DNA nucleotides to dark nucleons representing DNA triplets and it is not easy to imagine any simple mechanism making this possible. Already existing DNA triplets seem to be necessary.

11.3.3 Common Explanation For The Findings Of Montagnier And Gariaev

In the experiments of Montagnier's group [I97] the outcome is remote replication whereas the earlier experiments Gariaev's group [I87, I86] give evidence for phantom DNA and remote activation of DNA transcription by scattered laser light able to represented genetic code. There must be interaction between the test tubes in Montagnier's experiments and in the recent experiments of Gariaev's group observing remote replication there is explicit interaction between the test tubes due to the scattered laser radiation. Hence one expects a common underlying mechanism based on radiation between the tubes and phantom DNA.

1. The TGD based explanation [K47] of Montagnier's findings relies on the assumption that the homeopathic procedure generated a population of dark DNA nucleotides in the diluted system. The sequence of dilutions and shakings was like a series of environmental catastrophes

driving the evolution of dark DNA and also feeding metabolic energy to the system. The outcome was dark DNA population mimicking the original DNA in the test tube B. In the presence of DNA polymerase in tube B and second test tube A containing ordinary DNA the dark DNA was somehow able to generate ordinary DNA in tube B. The detailed mechanism for this remained open.

2. Could the scattered laser light have the same effect as the homeopathic procedure? This would require a direct transcription of dark DNA to ordinary DNA in the presence of DNA polymerase and nucleotides (only them!). It is very difficult to understand how this could happen. DNA polymerase very probably does not have the same catalyzing effect on dark DNA sequences as on ordinary DNA sequences. It is also difficult to imagine the build-up of ordinary DNA from nucleotides using dark nucleon sequences as templates: if frequency coded codons would serve as building bricks, situation would be simpler as already found.

3. One must not forget that the presence of the test tube A was essential in the experiment of Montagnier: communications between the test tubes crucial for the outcome must have taken place. The consistency between the two experiments could be achieved if the DNA in test tube A generated the counterpart of the scattered laser signal in Gariaev's experiments but certainly as a much weaker signal.

4. This signal should have been amplified somehow by the presence the dark DNA sequences in tube B so that it would have been able to generate critical amounts of conjugate of the original DNA amplified by DNA polymerase to the copy of the original. What suggests itself is a positive feedback loop ordinary DNA sequences $\rightarrow$ dark DNA sequences $\rightarrow$ ordinary DNA sequences..... causing the amplification of the weak signal so that it is able to induce remote replication by the proposed mechanism. This kind of feedback of signals propagating between magnetic bodies was assumed also in the model for the strange images produced by the irradiation of DNA sample by ordinary light interpreted as photographs of magnetic flux tubes containing dark matter [K1].

This model explains also the findings of the recent experiment (unpublished) of Gariaev. In this case the amplification by feedback mechanism could be present but might not be needed since the scattered laser radiation could give strong enough signal to produce the needed amount of conjugate DNA serving as a template. What is nice from TGD point of view that the consistency between the two experiments gives support also for the notion of dark DNA and its identification as phantom DNA.

11.3.4 Summing Up The Basic Assumptions Of The Mechanism

The basic assumptions of the model of remote replication deserve a short summary.

1. Bio-molecules would serve as receiving and sending quantum antennas forming populations with communications between members just like higher organisms. The molecules participating the same reaction would naturally have same antenna frequencies. Quarks and antiquarks at the ends of the flux tubes would code for different nucleotides and the frequencies associated with the nucleotides would be identical. The character of classical electromagnetic field would code for a particular nucleotide.

2. Remote replication and other remote polymerization processes would differ from the ordinary one only in that the phase transition reducing the value of Planck constant for the flux tube would not take place and bring the molecules near each other. Note that the fractal hierarchy of flux quanta: nucleotide flux tubes, codon flux tubes and flux sheets associated with DNA strands is essential.

3. The immediate product of remote replication would be the conjugate of the original DNA sequence and DNA polymerase would amplify it to the copy of the original DNA sequence. This prediction could be tested by using very simple DNAs sequences- say sequences consisting two nucleotides which are not conjugates. For instance, one could check what happens

if conjugate nucleotides are absent from the target (neither conjugate nor original DNA sequence should be produced). If the target contains conjugate nucleotides but no originals, only conjugate DNA sequences would be produced - one might hope in sufficiently large amounts to be detectable.

4. Frequency coding would be natural for quantum antenna interactions between ordinary DNA and its dark variant and also between dark variants of DNA, RNA, tRNA, and amino-acids. The reason is that dark nucleons represent the genetic code by entanglement and it is not possible to reduce the codon to a sequence of letters.

11.4 Possible Implications

The proposed realization of remote replication seems to have rather far reaching implications for the understanding of the mechanism of homeopathy and basic mechanisms of immune system as well as to the understanding of how DNA -dark nucleon sequence association. One can also interpret the proposed TGD based realization of the divisor code [K106] suggested by Khrennikov [K109] as frequency coding of DNA triplets by the value of Planck constant assignable to flux tubes emerging from DNA triplets.

11.4.1 Possible Relevance For Homeopathy And Immune System

TGD inspired vision about water memory assumes that the magnetic bodies of molecules dis-solved into water represent the molecules in terms of cyclotron frequencies characterizing its magnetic body. Molecules can lose their magnetic bodies as the hydrogen bonds connecting the molecule to the magnetic body are split. The population of these lost magnetic bodies would define a representation for the dissolved substance able to mimic it.

The hitherto unanswered questions concern the detailed structure of the magnetic body of the molecule and how it codes for the molecule. The hydrogen bonds connecting the molecule to the ordered water forming a kind of ice covering the molecule in the inactive state should be crucial aspect of the coding. If dark nucleon sequences are associated with the hydrogen bonds of this "ice layer" or generated in their splitting as I have proposed, one can ask whether dark nucleon sequences could characterize the molecular magnetic body. If so, cyclotron resonance frequencies or more general frequencies associated with the dark DNA sequences could code for the molecule. DNA sequences would define a universal language allowing for the system to name for polar molecules.

Quantum antenna mechanism would in turn associate ordinary DNA sequences with the dark nucleon sequences coding for the molecule. Hence one can imagine a development of a mechanism allowing the organism to modify its DNA by adding to it genes coding for proteins characterized by the same resonance frequencies as the magnetic bodies of the invader molecules. These proteins would couple strongly to the invader molecules via quantum antenna mechanism and the phase transition reducing Planck constant would allow them to catch the invader molecules by attaching to them. The fact that the DNA of immune system evolves very rapidly conforms with this vision.

11.4.2 Frequency Coding For DNA Sequences By The Value Of Planck Constant As A Realization Of Divisor Code

The realization of dark magnetic bodies of polar molecules in terms of dark nucleon sequences allows to understand the association of dark DNA with ordinary DNA, RNA, and tRNA making among other things possible the transcription of dark DNA to DNA and vice versa. Dark nucleon sequences would be associated with the magnetic bodies of DNA, mRNA, and tRNA. This would apply also to amino-acid sequences. Dark DNA would separate from ordinary DNA as it loses its magnetic body in the splitting of hydrogen bonds and suffers denaturation. Similar mechanism would cause denaturation of other biomolecules and would mean that they "lose their names" and thus information content and become mere organic molecules instead of living bio-molecules. This kind of association would make the emergence of the genetic code and its generalization to the naming of molecules by DNA sequences trivial.

Genetic code can be understood from the proposed natural correspondence between dark nucleon sequences and DNA, RNA, tRNA, and acmino-acids). I have however developed also another realizaton based on TGD based realization of so called divisor code first suggested by Khrennikov and Nilsson [K109] and the following argument allows to interpret in terms of frequency for fixed value of photon energy with frequencies coded by the value of Planck constant.

1. The observation of Khrennikov and Nilsson is following. Consider the integers n in the range 1, ..., 21 and obviously labeling amino-acids and let $k(n)$ the number of divisors of n. Define $B(k)$ as the number of integers n for which the number of divisors is k. It turns out that the numbers $B(k)$ are rather near to the numbers $A(k)$ of amino-acids coded by k codons. This suggests that given amino-acid A is coded by a product of prime $p(A)$, which alone characterizes it, and integer $n(A)$ in the range $1, ..., 21$. The product of integers characterizing the codon coding for A would be characterized by the product of $p(A)$ and some factor $r(A)$ of $n(A)$. With these assumptions given codon would code for only single amino-acid and the number of DNAs coding for amino-acid A is the number of the factors $r(A)$ of $n(A)$. The codons coding for A would be coded by integers $p(A)r(A)$ such that $r(A)$ divides $n(A)$. The safest assumption would be that the primes $p(A)$ satisfy $p(A) > 19$ so that $p(A)$ does not divide $n(A)$ for any A. If $p(A)$ is as small as possible the value spectrum of $p(A)$ is

$$\{23, 29, 31, 37, 41, 43, 47, 53, 59, 61, 67, 71, 73, 79, 83, 89, 97, 101, 103, 107, 109\} \ .$$

   If one assumes that the two additional amino-acids coded in some cases by non-vertebrate genetic code correspond to primes also the primes $113, 127$ are included.

   What is interesting is that Mersenne prime $M_7 = 2^7 - 1 = 127$ appears in the model of genetic code based on the notion of Combinatorial Hierarchy [K44]. This model assumes that DNA codons correspond to 64 integers in the range $1, ..., 127$. This realization of the genetic code cannot however be consistent with the divisor code realized in the proposed manner since it would require that the integers $n(A)p(A)$ belong to the range $1, .., 127$. The prime factors of these integers can however belong to this range.

2. The TGD inspired proposal [K106] was that the flux tube assignable to amino-acid A corresponds to $\hbar = p(A) \times n(A)\hbar_0$ whereas the DNA triplet (for quark-antiquark coding nucleotide rather than triplet) coding for it is characterized by $\hbar = p(A) \times r(A)\hbar_0$ such that $r(A)$ divides $n(A)$.

3. This proposal could be interpreted in terms of frequency coding by quantum antenna mechanism. For a given photon energy E wave length would be coded by the value of $\hbar$ and one would have $\lambda_n = n\lambda_0$, $n = p(A)n(A)$ for amino-acids and $n = p(A)r(A)$ for codons. The condition that flux tube lengths are same for different DNA triplets would be satisfied if the common length of the flux tubes is an integer multiple of λ_0 proportional to the product of all integers appearing as factors in the integers coding for amino-acids. The common length of the flux tubes would be therefore proportional to the product $\prod_A p(A) \prod_A r_A$.

11.5 More Precise View About Remote DNA Replication

Both Luc Montagnier [I96, I97] and Peter Gariaev [I104] have found strong evidence for what might be called remote replication of DNA. I have developed a TGD inspired model for remote replication using the data from Peter Gariaev [K114], who has developed the notion of wave DNA [I86] supported by Montagnier's findings.

Polymer chain reaction (PCR) [I53] provides a way to build copies of piece of DNA serving as template. Once single copy is produced, it serves as a template for a further copy so that exponential amplification is achieved. Montagnier's and Gariaev's works suggest however that the synthesis of DNA could also occur without a real matrix DNA as remote replication. According to the proposal of Gariaev [I86, I126] DNA template would be remotely represented as what he calls wave DNA. Montagnier [I97] uses 7 Hz ELF radiation to obtain the effect whereas Gariaev [I104] uses scattering of laser light into large interval of frequencies to achieve the effect.

In TGD approach magnetic body containing dark matter with large Planck constant, the associated cyclotron radiation for which energy scale is proportional to effective Planck constant $h_{eff} = n \times h$ having large values implying conjectured macroscopic quantum coherence of living matter, dark analog of DNA represented as dark proton sequences at magnetic flux tubes and accompanying ordinary DNA, plus reconnection of U-shaped magnetic flux tubes assignable to the magnetic bodies of biomolecules and allowing them to recognize each other, are the basic elements. The model has evolved from the attempts to understand water memory and homeopathy in TGD framework [K47].

Both 7 Hz ELF radiation and scattering of laser light would both generate dark photon (large Planck constant) spectrum with a wide spectrum of frequencies but with the same energy which in Gariaev's experiments would naturally be the energy of scatter laser light. The dark photons would provide representation for DNA codons. If 7 Hz frequency radiation involves dark photons with energies of visible photons transforming to ordinary photons before scattering from DNA the outcome would be same as in Gariaev's experiments.

This picture conforms with Gariaev's hologram idea and also with TGD based vision about living matter as a conscious hologram [K17]. The laser beam that Gariaev has used and the 7 Hz irradiation (involving dark ELF photons at bio-photon energies) would act as a reference beam allowing to read a biohologram coded by DNA and its magnetic body. The outcome is dark photons with same energy but with varying values of Planck constant and thus with varying frequencies propagating along magnetic flux tubes to the target, which could be exclusion zone (EZ). Flux tubes are characterised by h_{eff} and magnetic field strength B_{end} determining cyclotron frequency (coded by the transversal area by flux quantization if monopole flux is in question). Metabolic energy is needed to create EZ and could be provided either by the radiation itself or by the repeated heating. Negentropic entanglement is generated and creates the correlation between dark (phantom) DNA codons and ordinary DNA codons.

The following involves same elements as the model discussed in [K114] but there are also new elements due to the developments in the model of dark DNA allowing to imagine a detailed mechanism for how water can represent DNA and how DNA could be transcribed to dark DNA. The transcription/association represents a rule and rules are represented in terms of negentropic entanglement in TGD framework with pairs of states in superposition representing the instances of the rule. Transition energy serves as a characterizer of a molecule - say DNA codon - and the entangled state is a superposition of pairs in which either molecule is excited or dark DNA codon is excited to higher cyclotron state with same energy: this requires tuning of the magnetic field and sufficiently large value of h_{eff} at the flux tube. Negentropic entanglement is due to the exchange of dark photons: this corresponds to wave DNA aspect. Dark cyclotron photons also generate negatively charged exclusion zones (EZs) discovered by Pollack and in this process transform part of protons to dark ones residing at the magnetic flux tubes associated with EZs and forming dark proton sequencies.

11.5.1 Some Background

The model for remote replication involves the following basic building bricks.

1. Dark variant of DNA realized as dark proton strings representing dark nuclei.

2. The identification of bio-photons as decay products of dark cyclotron photons with large value of h_{eff} having universal energy spectrum due to the condition $h_{eff} = h_{gr}$.

3. TGD explanation for the fourth phase of water discovered by Pollack [L22] and characterized by negatively charged exclusion zones EZs generated by radiation.

4. A model for the radiative coding of DNA creating 1-1 correlation between ordinary and dark DNA codons and between two dark DNA codons.

Dark DNA as dark proton strings

TGD leads to a model of nuclei as nucleons strings [L2]. The model generalizes to the dark matter sector [L2, K47].

1. I have proposed the notion of dark DNA realized as dark proton sequences (3 quark states), which I have argued ton basis of a simple model to form representations for DNA, RNA, amino-acids and even tRNA is central for TGD inspired biology. Biochemistry would define only a secondary representation for more fundamental realization of genetic code and analogs of basic biomolecules in terms of dark nuclear physics.

   I have conjectured that translations, transcription, etc generalize and apply to pairs of ordinary and dark and dark and dark DNA and amino-acids. One could even consider that dark DNA would make possible induction of genetic changes: transfer dark DNA inside germ cells and transform them to ordinary DNA and attach to existing DNA. If dark DNA can be generated by radiation as wave DNA notion suggests then radiation from other cells to germ cells could induced genetic changes. Living systems would have kind of Research and Discovery apartment developing new candidates for genes. Evolution would be the opposite for blind random trials.

2. I have also proposed that immune system could have developed from what is basic mechanism of homeopathy and water memory. The magnetic bodies of water clusters mimic invader molecules - or rather their magnetic bodies. What is needed is a representation for cyclotron frequencies so that radiation would emerge in this phase. Cyclotron frequency spectrum would represent the invader and the simplest mimicry of invader molecule would be water structure with magnetic body characterized by same cyclotron frequency spectrum: water memory in short. Also the braiding of the magnetic body of the invader might be mimicked.

   Protein folding might be a chemical representation for this braiding and the proteins of immune system might mimic the braidings of the magnetic bodies of the invader molecules. DNA in turn would give a symbolic representation of proteins allowing to construct them when needed. Ordinary DNA and proteins would have been preceded by dark DNA and dark proteins. I have even proposed an interpretation of genetic code based on the idea that it represents the dynamical evolution of braiding of the magnetic body - or 2-braiding [K76].

   The basic mechanism of directed attention or sensing the presence of the invader molecule would be reconnection of U shape flux tubes of the magnetic bodies of the two system. Also resonant interaction by cyclotron radiation inducing cyclotron transitions is expected to be an essential piece of the mechanism. Magnetic body of water cluster could tune the thickness of flux tube so that the magnetic field is same as that in the flux tube of invader molecule so that primitive consciousness and act of free will would be involved.

3. Suppose that DNA codes for proteins, their cyclotron frequency spectrum and their braiding and knotting in protein folding in turn representing invader molecule. Is the frequency spectrum all that is needed to represent DNA and construct its dark variant? The experiments of Benveniste and followers [I82, I83] suggest that invader molecules are indeed represented by the cyclotron frequency spectrum alone. This would suggest connection with wave DNA concept.

Universality of cyclotron energy spectrum and bio-photons as decay products of dark photons

There are good empirical motivations [K72] to expect that the cyclotron energy spectrum is universal and in the range of bio-photon energy spectrum. This is achieved if h_{eff} is proportional to the mass m of the charged particle so that cyclotron energy $\hbar_{eff}eB/m$ is independent of mass and same for all charged particles.

Universality follows also from the condition that gravitational and biological Planck constants are identical: $h_{gr} = h_{eff}$, where $\hbar_{gr} = GMm/v_0$ is the gravitational Planck constant introduced by Nottale and assigned with the flux tubes mediating gravitational interaction in TGD Universe. The condition states that electromagnetic and gravitational flux tubes have same the value of effective Planck constant meaning that also gravitation would become a key player in biology.

Fourth phase of water, EZs, and metabolic role of cyclotron radiation

The experiments of Pollack [L22] suggest a partial answer to the question. in terms of what he calls fourth phase of water containing negatively charged regions, exclusion zones (EZ) of size up to 200 micrometers.

1. Irradiation of water by visible light generates negatively charged regions which he calls exclusion zones (EZs). The energy goes to the formation of electric voltage between exterior and interior and is analogous to cell membrane potential. Predecessor of cell could be in question. Some fraction of protons must go outside the system and my proposal is that it goes to magnetic flux tubes and forms dark proton sequences defining the analogs of basic bio-molecules. The $H_{1.5}O$ stoichiometry of EZs [L22] characterizing also earlier findings suggesting that one fourth of protons of water are dark in attosecond time scale (not visible in electron scattering and neutron diffraction) suggests that every fourth proton disappears from EZ. This anomaly was one of the strong motivations for taking the idea about dark matter as large h_{eff} phases seriously [K38].

   These structures would be involved also with water memory and homeopathy and immune system would have emerged from these. Free energy researchers know these regions quite well [H2] (no-one of course takes them seriously!) and they can be generated by just feeding energy to system used as metabolic energy. In homeopathy the mechanical agitation would do this and induce replication and perhaps even evolution of the resulting primitive lifeforms. Cavitation, use of strong electric field, maybe even heating used in PRC, etc... are possible mechanisms of energy feed.

2. The cyclotron radiation at cyclotron frequencies associated with flux tubes emanating from DNA codons could provide the energy needed to induce the formation of EZs. This would be the first function for the radiation.

3. If the DNA end of flux tube contains dark proton in state which corresponds to the DNA in one-one manner then the mass of the dark proton state would assign to it a unique cyclotron frequency distinguishing between DNA codons. The challenge is to understand the mechanism of DNA dark DNA pairing and dark DNA-dark DNA pairing and one expects resonant binding by exchange of dark cyclotron photons.

Pairing ordinary and dark DNA codons and two identical dark DNA codons by negentropic entanglement

One should understand the pairing of ordinary and dark DNA. As a matter fact, this pairing defines a realization of the genetic code as a physical 1-1 correlation of DNA codons with some physical states. I have consider this kind of realizations also in the model of DNA as topological quantum computer. The following realization relies on resonant interaction by exchange of dark cyclotron photons and can be seen as radiation based.

1. The most natural association between ordinary and dark DNA would via energy resonance. The energy for some molecular transition of DNA (in bio-photon energy range by argument below) would be same as cyclotron energy for the codon with large value of $h_{eff} = n \times h$ making cyclotron energy large.

2. By suitably tuning the value of the magnetic field B associated with the flux tube accompanying ordinary DNA codon the dark cyclotron energy can be tuned to be equal to the value of some biochemical transition energy of DNA, which is in visible and UV range typically - that is in the energy range of bio-photons.

3. Classically DNA codon and its dark variant can be thought of as exchanging forth and back dark photon at resonance frequency and become strongly correlated in this manner like tennis players during game. Quantum mechanically one has quantum entangled Schrödinger cat like state in which state pairs have same total energy but individual states do not have well-defined energy.

4. The correlation between dark proton states at two ends of flux tube would be realized as formation of bound state via resonant exchange of dark cyclotron photons. Negentropically entangled [K60] superposition for which simplest the possible form is $|n\rangle|n+1\rangle + |n+1\rangle|n\rangle$ of paired cyclotron states would be generated. DNA and dark DNA codons would pair to a negentropically entangled state in similar manner. Recall that in TGD framework negentropic entanglement (NE) carries potentially conscious information: the state represents a rule whose instances correspond to the state pairs in the superposition [K60].

5. One can consider also 3-particle NE of DNA codon and 2 dark DNA codons which is superposition of three 3-particle states with one particle excited to higher energy state with the same energy. DNA codon would be excited chemically and dark codons excited to cyclotron state ($n \to n+1$). 3-dimensional permutation symbol defines this kind of state. Also NE for larger number of particles is possible.

The tuning of the flux tube magnetic field to make cyclotron energy equal to chemical transition energy is possible for arbitrary biochemical transition energies and the association of dark proton states to arbitrary biomolecules is in principle possible via same mechanism. This would be essentially a symbolic representation of biomolecule, a name for molecule. If one has some number of different molecules able to form sequences, these sequences can be remotely reconstructed by using the cyclotron frequencies and transversal flux tubes associated with the template to generate the EZs and the name of the polymer to which the building bricks bind resonantly.

If the condition $h_{eff} = h_{gr}$ holds true, one can use instead of dark proton sequences sequences of *any* dark charged particles - say electrons and ions. Hence almost an unlimited repertoire of representations arises. These correspondences need not to be one-one. For instance, DNA-amino-acid 64-to-20 correspondence is possible to realize with the help of dark variants of DNA codons and amino-acids and also the partially or totally dark variants of this correspondence are possible.

This pairing mechanism would allow resonant interactions of the ordinary DNA codons in water and dark DNA codons induced by the dark cyclotron radiation and could play key role also in ordinary DNA replication and also in the remote replication reported by Montagnier [I97] and Gariaev [K114]. A phase transition reducing h_{eff} would bring ordinary and dark codon together and ordinary biochemistry would take care of the rest. Clearly, this mechanism would also allow biomolecules connected by magnetic flux tubes to find each other in molecular soup with pairing following by a phase transition reducing h_{eff}.

11.5.2 Does Remote Replication Apply Same Mechanism As MimicryOf Invader Molecules In The Case Of Water Memory?

Somehow the irradiation of water sample with the cyclotron radiation generated by real DNA should induce or be involved with the generation of dark DNA representing the ordinary DNA and the PCR process would use this dark DNA as template an involves pairing of ordinary and dark DNA nucleotides. How this could happen in TGD Universe?

The mechanism of remote DNA replication without chemical template would be essentially the same as in the TGD based model of water memory [K47] underlying also the model of homeopathy circumventing the ultra-naïve skeptic argument that homeopathy is not possible because the density of molecules dissolved in water is practically zero.

The cyclotron frequency spectrum allows to create EZ whose magnetic body mimics the invader molecule. Resonant formation of negentropically entangled pairs would define a realization of genetic code based on radiation and dark cyclotron radiation would give rise to the formation of EZs and accompanying dark proton sequences.

In the recent case invader molecule would be replaced with DNA expressing its presence using dark cyclotron radiation propagating along the flux tubes transversal to codons and forming part of the magnetic body of DNA. The magnetic flux tube of ordinary DNA codon realizing dark proton sequence as dark variant of DNA codon would generate its own representation by generating EZs in water.

The rules would be following.

1. Magnetic fields at U-shaped flux tubes associated with codons and dark codons must be equal so that also cyclotron frequencies coding for dark proton masses and therefore for dark proton

states would be equal so that frequency and energy resonance is possible and negentropically entangled state is formed. This assigns by resonance mechanism to the second end of flux tube same dark proton state as to the end near ordinary DNA. Recall that U-shape is essential for bio-super-conductivity based on large value of h_{eff} making possible large and negative spin-spin interaction energy for electrons of pair located at parallel flux tubes [K19, K77].

As described, binding is generated by resonant exchange of dark cyclotron photons between the ends which are in superposition of different cyclotron states. Magnetic field value in turn corresponds directly to ordinary DNA codon - or rather its transition in bio-photon energy range. It is essential that the value of magnetic field codes for ordinary DNA codon via a biochemical transition energy associated with it. One can imagine that magnetic body can tune the value of field by changing the transversal area of the flux tube carrying monopole flux (possible in TGD due to the CP_2 topology). Similar tuning would be involved when the magnetic bodies assignable to EZs detect possible invader molecules. Interestingly, the impurity molecules inside EZs are removed by unknown mechanism citebbioPollackYoutube.

2. Dark DNA codons associated with DNA would have U-shaped flux tubes which for large h_{eff} would extend to the water sample containing building bricks of DNA and catalyst. The flux tubes associated with dark DNA and building bricks of ordinary DNA would reconnect resonantly and lead to remote replication of DNA strand.

This option is definitely not the only possibility one can imagine but represents the general principle. For instance, one can consider using only DNA-dark DNA complex and inducing h_{eff} increasing phase transition transferring the dark DNA strand to the volume of the water sample. The mechanism allows also to consider remote translation of genes to proteins. The possible medical applications of this in a situation in which the DNA of the patient has suffered a mutation causing a disease are obvious.

11.6 Remote replication again

In TGD inspired vision about quantum biology relying on the notion of magnetic body (MB) carrying dark matter as phases of ordinary matter with effective Planck constant $h_{eff} = n \times h_0$ one ends up with the notion of dark DNA realized as sequences of dark protons and to the surprising finding that dark proton triplets realize vertebrate genetic code and basic biomolecules DNA,RNA,tRNA, and amino-acids [L28, L41].

The objection against dark photon 3-chords (3-photon states) is that the simultaneous emission of 3 dark photons used in communications as 6-bit unit is extremely non-probable. A possible solution of the problem is that dark photons carry number theoretic color associated with Z_3 subgroup of Galois group. Number theoretic color confinement would imply that only 3-chords can appear as asymptotic states analogous to baryons. If dark protons are also number theoretic color triplet, dark codons must consists of 3 protons and therefore also ordinary codons have 3 letters.

The findings of Montagnier *et al* [I97] (`http://arxiv.org/abs/1012.5166`) raise the possibility of remote replication of DNA. Montangier's experiment involves two chambers A and B. A contained water and genes and B water and DNA nucleotides. There were channels between the chambers but so thin that DNA could not get through. Besides this there was present em field with 7 Hz frequency. Same genes as in A appeared also in B. As if remote replication of genes in A had happened in B. I have written an articles about Montagnier's findings [L16, L21]. Gariaev has reported similar phenomenon already before Montagnier *et al*: we wrote together an article discussing TGD based model for the finding [K114].

How did the genetic information pass to B and how the remote replication took place? Somehow the radiation made the remote replication possible or at least more probable. Clearly the information about gene - not only about codons but also about their order and relative positions - should have been communicated from A to B. I have already earlier considered this problem but found no satisfactory solution to it.

Concerning the role of the 7 Hz frequency, there are two hints.

1. The nominal value of the lowest Schumann frequency is 7.8 Hz, not far from 7 Hz. Could one think that macroscopic quantum coherence in the scale of Earth was involved. 7.8 Hz

correspond to wavelength equal to circumference of Earth.

"Endogenous" magnetic field $B_end = .2$ Gauss identifiable as the monopole flux part of the Earth's magnetic field $B_E = .5$ Gauss explains the findings of Blackman [J12] and others about quantal looking effects of radiation at frequencies seem to be multiples of cyclotron frequencies of biologically important ions.

The problem is that the energies of cyclotron photons are ridiculously small for ordinary value of Planck constant. This was one of the motivations for the hypothesis that dark matter corresponds to phases of ordinary matter with effective Planck constant $h_{eff} = n \times h_0$ [K76, K77, K78]. The cyclotron frequency of K ion is $f_c(K^+) = 7.1$ Hz. The flux tubes with length of corresponding cyclotron frequency are also of the order of Earth circumference.

This raises several questions.

1. Did water generate flux tubes with magnetic field with frequency equal to $f_c(K^+) = 7.1$ Hz and strengthening coupling to a radiation with Schumann frequency or K cyclotron frequency or both so that the communications with the MB of Earth or/and layer of MB corresponding to K cyclotron was strengthened? The TGD based mechanism of water memory [K47] would be involved.

2. Did this make the remote replication more probable? How?

3. What DNA actually looks like in TGD Universe? What actually happens in DNA replication? What could happen in remote DNA replication?

In the sequel the questions whether cyclotron frequency or Schumann frequency or both were involved and how their presence made possible remote replication remain without detailed answer although it is clear that the presence of dark photons with this frequency should make possible the control by MB generating coherence of ordinary matter in the scale determined by the sizes of the chambers. These questions however led to a considerable increase in the understanding of dark variants of genetic code predicted by TGD [L28, L20, L50].

1. To understand remote replication one must understand replication. Dark codons do not decompose into letters like chemical codons: this poses strong constraints on the replication and transcription if one assumes DDNA-DNA-pairing. These constraints strongly suggests that the nucleotides in the water environment of DNA are not actually free but form loosely bound triplets representing codons and bound with DDNAs. This means a new variant of genetic code realizing codons as loose triplets of nucleotides in the water environment.

2. This proposal brings in mind TGD based model for viruses, which can decompose into pieces shared between several host cells and re-combine later as also the observation that the dense states of bacteria population have resemblance to multi-cellular embryos. The common TGD inspired explanation [L54] would be that the pieces of virus and cells of bacterial population are connected by magnetic flux tubes and form a single loosely bound unit at the level of MB. The prediction is that replication occurs in codon-wise manner: this has been observed to be possible for RNA [L44]. It might be that the loose nature of exotic DNA codons allows this to occur quite generally.

3. Remote replication in this framework reduces to ordinary replication in TGD sense if also dark genes are formed by attaching flux tubes characterizing dark codons to a long flux tube associated with gene. Remote replication requires that the portion of dark gene accompanying ordinary gene is transferred from chamber A to chamber B in the experiment of Montagnier.

11.6.1 Three variants of genetic code

The notions of MB and view about dark matter leads to 3 variants of genetic code.

1. The notion of MB suggests that dark proton sequences assumed to explain Pollack effect (`http://tinyurl.com/gwasd8o`) [L22] realize dark genetic code. Dark DNA (DDNA) codon

would correspond to 3-proton triplet assignable to closed flux tubes attached to a a long flux tube by U-shaped flux tube appendix giving rise to dark gene (http://tinyurl.com/jgfjlbe). Attaching means formation of U-shaped appendices from long flux tube and DDNA codon which reconnect to a pair of flux tubes. 3-proton states define dark analogs of DNA, RNA, tRNA, and amino-acids (DDNA, DRNA, DtRNA, DAA) [L28, L41]. The numbers of DDNAs coding for given DAA are same as for vertebrate genetic code.

2. Second dark code is needed for communications and realizes genetic codons as dark 3-photon states - 3-chords of bio-harmony [L20, L47, L50] (http://tinyurl.com/yad4tqwl). The model emerged from a model of musical harmony based on icosahedron and tetrahedron. 12-note scale is identified as a Hamiltonian cycle - a path going through all 12 vertices of icosahedron - such that going from vertex to neighbor corresponds to quint. Hamiltonian cycles have cyclic group Z_n,where $n = 0, 2, 4, 6$ is the order of the group, as symmetries. $n = 0$ corresponds to chaotic orbit and disharmony. Each of the 20 faces - triangles - corresponds to a chord of given harmony.

   One identifies the orbit of given face as DAA coded by faces (DDNAs) at the orbit. By combining 3 harmonies with $n = 6$, $n = 4$ and $n = 2$ one obtains 20+20+20 chords and the numbers of DNA coding given AA are essentially those in vertebrate code. By gluing tetrahedron to one face one obtains 4 additional chords (DDNAs) and 1 additional note very near to one of the notes of Pythagorean scale, whose problem is that it does not quite close. The numbers for analogs of DNA codons coding for for given DAA are same as for vertebrate code.

   The chords would be represented as "music of light" as states of 3 dark photons. Music expresses and creates emotions and bio-harmony would provide a physical correlate for emotional states at molecular level [L45].

3. Dark codes would be fundamental and chemical code would be their mimicry. One expects DDNA-DNA pairing with DDNA codons represented as dark proton triplets. DDNA codons and dark photon chords have no decomposition to letters (chinese and western languages provide an analog). This suggests that DNA replication and transcription cannot take letter-wise but but codon-wise. Amazingly, there is evidence that DNA replicates in codon-wise manner during RNA era: I have commented this in [L44].

   Nucleotides/letters in the water environment of DNA double strand should appear as loosely bound but correlated triplets of nucleotides associated with closed flux tubes containing dark DNA codon. They would represent exotic DNA codons. This would force fixed order of nucleotides essential for the code. By absence of valence bonds between nucleotides they would be effectively free but strongly correlated. This representation of the code would be crucial for replication and transcription.

These 3 codes allow to understand replication and transcription of DNA replaced in TGD with DDNA-DNA pair. The prediction is that the replication takes place codon by codon and might kill the model.

A model of replication based on this picture generalizes to remote replication suggested by the findings of Montagnier [I97]. The DDNA codons of ordinary DNA strand would be attached with a long side of closed flux tube as dark gene. In remote replication h_{eff} of dark gene would change and dark gene would be transferred to chamber B from A. After that the replication would proceed as usual.

11.6.2 An objection against bio-harmony

There is a serious objection against the realization of dark genetic code in terms of bio-harmony. The emission of 3 dark photons simultaneously looks extremely non-probable process.

Number theoretical physics suggests a solution of the problem. Number theoretical physics [L35] (http://tinyurl.com/zylrd7w) is a central part of quantum TGD and quantum biology and provides physical correlates for cognition. It explains dark matter as $h_{eff} = nh_0$ phases of ordinary matter with n identified as order of Galois group of extension of rationals and as dimension of extension. This picture predicts automatically evolution as increase of n in quantum jumps.

1. There is analogy with color confinement. Baryons consist of 3 quarks. Color symmetry is a symmetry of strong interactions and quarks form color triplets. Free quarks do not appear in the final states, which givs rise to color confinement: only color singlets, in particular baryons consisting of 3 quarks and mesons consisting of quark and antiquark are possible.

   This suggests that also now there must be a symmetry such that dark photons have new quantum numbers, which vanish for physical states such as dark photon triplets.

2. What these quantum numbers could be? The only candidate, which comes in mind are discrete quantum numbers related to the Galois group of extension of rationals defining number theoretic symmetry. For ordinary $h = 6h_0$ Galois group has $n = 6$ elements and equals to $Z_6 = Z_2 \times Z_3$.

   It appears as subgroup of higher Galois groups for which $h_{eff} = n \times h = 6nh_0$ one would have extension of extension. Z_3 confinement would require 3-photon states, which are Z_3 singlets with number theoretic colors summing up to zero. One would obtain only 3-chords. Ordinary photons would be Z_3 singlets.

3. Also the 3 protons of DDNA codon could form Z_3 triplet. Number theoretic color confinement would allow only 3-proton triplets. Genetic code is predicted correctly and the number letters in the codons is predicted to be 3.

   This raises two interesting questions.

1. Quantum-classical correspondence (QCC) is a exact part of TGD. Therefore I have considered the possibility that all physical symmetries could have number theoretical space-time correlates. However, at space-time level one cannot have representations of color group with non-vanishing triality $t = 0, \pm 1$. Same applies to spin half-odd integer representations of rotation group. Could $SU(2) \times SU(3)$ representations with triality $t = \pm 1$ and spin half-odd integer have triplet representation of Z_3 and double representation of Z_2 as space-time correlates? Z_6 would be the minimal Galois group allowing to realize spin and color for quarks.

2. Number theoretical physics predicts that Galois group for any extension of rationals acts as new hidden discrete symmetry. Could number theoretical confinement implying new selection rules be true quite generally? The larger the degree n of extension (h_eff), the larger the scale in which confinement holds true, is. For instance, genes could be analogs of color singlet many particle states for a larger subgroup.

This is not the only option. I have already earlier considered with Peter Gariaev [K114] a proposal in which dark photons would communicate the genetic information from A to B. The problem is how the massless extremals (MEs) [K8] associated with them can be parallel and of same length: this would require that they form a quantum coherent entity. Could one consider a modification of the above proposal assuming that gene is an entity of N codons confined number theoretically? Could one can speak about dark photon genes as composites of N dark photon 3-chords? The information would be sent by dark photon gene representing entire music piece, as one might say. In chamber B energy-frequency resonance would generate a linear configuration of exotic codons, which would reduce to DDNA-DNA pair when h_{eff} is reduced.

11.6.3 DDNA-DNA, DDNA-DDNA, DDNA-exotic DNA pairings

The idea about MB as boss of BB suggests that DNA is accompanied by DDNA. DDNA would be the fundamental DNA and ordinary DNA emerged later as a kind of mimicry and there would be DDNA-DNA pairing.

The basic problem problem is that DDNA codons do not allow decomposition into letters like DNA codons. It seems that replication and transcription must occur codon by codon rather than letter by letter. For translation of mRNA this is indeed the case: tRNA are the basic objects. Could this be true in modified sense also for replication and transcription? In fact, RNA can replicate in codon-wise manner [L44]. Could this occur quite generally, and could the codons for replication believed to occur letter-wise be present in a latent manner?

DNA and DDNA codons

At least 3 new kind of codons are predicted (`http://tinyurl.com/yygqen5g`).

1. Also ordinary DNA codons involve flux tubes. Valence bonds between nucleotides of DNA strand and hydrogen bonds in double strand involve flux tubes or pairs of them.

2. DDNA codons are paired with ordinary DNA codons of DNA strand. DDNA codons would correspond to dark proton triplets at flux loops being analogous to tritium and ^{3}He. The model for remote replication requires that DDNA codon loops are connected to long closed dark gene flux loop by U-shaped appendages - attached to dark gene.

   If DDNA and DNA codons are paired with ordinary DNA by energy resonance there is no need for flux tube contacts between the triplets.

3. Dark codons as dark photon 3-chords are predicted. Couple to DDNA by energy-frequency resonance and to DNA by energy-resonance.

4. Exotic DNA codons are required by the model of replication. DNA nucleotides in environment would combine to exotic codons paired with DDNA codons.

What various pairings do look like?

There would be 3 kinds of pairings. This would predict that nucleotides appear as apparently free entities in the water environment.

1. DDNA-DNA pairing in DNA strand. Different values of h_{eff} do not allow flux tubes contacts. Energy resonance only.

2. DDNA-DDNA pairing in DNA double strand is not necessary in geometric sense as flux tube connections because hydrogen bonds pair DNA codons and energy resonance pairs DDNA strands to DNA codons. DDNA codons could be however located along dark gene flux tube and attached to it by flux tube pairs.

3. DDNA-exotic DNA pairing would take place in environment. Nucleotides of exotic DNA would be attached to closed DDNA codon flux tubes. h_{eff} would be larger than for DDNA codon in double strand. There would be no valence bonds between nucleotides. The ordering of letters would be forced by flux tube containing the dark codon and energy resonance. One obtains correct codon if the orientation of the flux tube matters (ABC and BCA correspond to different energies in energy resonance). Strong parity breaking allowed by TGD and realized in living matter would imply it.

   This would solve the basic problem. Codon would be secretly present since there would be no valence bonds, which together with small string tension would mean that nucleotides are effectively free.

4. It is of course not clear whether this is enough to explain experimental findings. If one can demonstrate experimentally that the build-up of DNA strand in replication really occurs in letter-wise manner, the proposed model must be modified (not of course clear whether this is possible). The codon-wise coding, which can occur for RNA [L44] could be understood if the value of h_{eff} for DRNA strand can be same or nearly the same as in RNA strand.

11.6.4 Did RNA replicate in codon-wise manner during RNA era?

There was an interesting popular article in Spacedaily with title "*Scientists crack how primordial life on Earth might have replicated itself*" (see `http://tinyurl.com/y92ng5vd`). The research paper [I93] is titled "*Ribozyme-catalysed RNA synthesis using triplet building blocks*" and published in eLife (see `http://tinyurl.com/ya5qyjfn`).

It is possible to replicate unfolded RNA strands in Lab by using enzymes known as ribozymes, which are RNA counterparts of enzymes, which are amino-adic sequences. In the presence of folding the replication is however impossible. Since ribozymes are in general folded, they

cannot thus catalyze their own replication in this manner. The researchers however discovered that the replication using RNA triplets - genetic codons - as basic unit can be carried out in laboratory even for the folded RNA strands and with rather low error rate. Also the ribozyme involved can thus replicate in codon-wise manner. For units longer than 3 nucleotides the replication becomes prone to errors.

These findings are highly interesting in TGD framework. In TGD the chemical realization of genetic code is not fundamental. Rather, dark matter level would provide the fundamental realizations of analogs of DNA, RNA, tRNA, and amino-acids as dark proton sequences giving rise to dark nuclei at magnetic flux tubes [L41] (see `http://tinyurl.com/yalny39x`). Also ordinary nuclei correspond in TGD Universe to sequences of protons and neutrons forming string like entities assignable to magnetic flux tubes.

The basic unit representing DNA, RNA and tRNA codon and amino-acid would consist of 3 entangled dark protons. The essential aspect is that by entanglement the dark codons do not decompose to products of letters. This is like words of some languages, which do not allow decomposition to letters. This representation is holistic. As we learn to read and write, we learn the more analytic western view about words as letter sequences. Could the same hold true in evolution so that RNA triplets would have come first as entities pairing with dark RNA codons from from dark proton triplets as a whole? Later DNA codons would have emerged and paired with dark DNA codons. Now the coupling would have have been letter by letter in DNA replication and transcription to mRNA.

It is intriguing that tRNA consists of RNA triplets combined from amino-acids and analogs of mRNA triplets! The translation of mRNA to amino-acids having no 3-letter decomposition alone forces the holistic view but one can ask whether something deeper is involved. This might be the case. I have been wondering whether during RNA era RNA replicated using a prebiotic form of translational machinery, which replicated mRNA rather than translated RNA to protein formed from amino-acids (AAs) with AA serving as a catalyst.

1. During RNA era amino-acids associated with pre-tRNA molecules would served as catalysts for replication of RNA codons. The linguistic mode would have been "holistic" during RNA era in accordance with the findings of the above experiments. RNA codon would have been the basic unit.

2. This would have led to a smaller number of RNAs since RNA and RNA like molecules in tRNA are not in 1-1 correspondence. A more realistic option could have been replication of subset of RNA molecules appearing in tRNA in this manner.

3. Then a great evolutionary leap leading from RNA era to DNA era would have occurred. AA catalyzed replication of RNA would have transformed to a translation of RNA to proteins and the roles of RNA and AA in tRNA would have changed. [Perhaps the increase of h_{eff} in some relevant structure as quantum criticality was reached led to the revolution]

4. At this step also (subset of) DNA and its transcription to (a subset of) mRNA corresponding to tRNA had to emerge to produce mRNA in transcription. In the recent biology DNA replicates and is transcribed nucleotide by nucleotide rather than using codon as a unit so that helicases and DNA and RNA polymerases catalyzing replication and transcription should have emerged at this step. The ability of DNA to unwind with the help of helicase enzyme helping DNA to unwind is essential for the transcription and translation of DNA. Therefore helicase must have emerged together with the "analytic linguistic mode" as an analog of written language (DNA) decomposing codons to triplets of letters. This would been a crucial step in evolution comparable to the emergence of written language based on letters. Also the counterpart of RNA polymerase and separate RNA nucleotides for transcription should have emerged if not already present.

   An alternative option would involve "tDNA" as the analog of tRNA and the emergence of helicase and polymerases later as the transition from holistic to analytic mode took place.

   The minimal picture would be emergence of a subset of DNA codons corresponding to RNAs associated with pre-tRNA and the emergence of the analogs of helicase and DNA and RNA polymerases as the roles of amino-acid and RNA codon in tRNA were changed.

5. How DNA could have emerged from RNA? The chemical change would have been essentially the replacement of ribose with de-oxiribose to get DNA from RNA and U→ T. Single O-H in ribose was replaced with H. O forms hydrogen bonds with water and this had to change the hydrogen bonding characteristics of RNA.

   If the change of $h_{eff} = n \times h_0$ was involved, could it have led to stabilization of DNA? Did cell membrane emerge and allow to achieve this? I have proposed [L41] (see `http://tinyurl.com/yalny39x`) that the emergence of cell membrane meant the emergence of new representation of dark genetic code based on dark nuclei with larger value of h_{eff}.

   Remark: One has $h = 6 \times h_0$ in the most plausible scenario [L29, L43] (see `http://tinyurl.com/goruuzm` and `http://tinyurl.com/y9jxyjns`).

The communication between dark and ordinary variants of biomolecules involves resonance mechanism and would also involve genetic code represented as 3-chords, music of light, and it is interesting to see whether this model provides additional insights.

1. The proposal is that 3-chords assignable to nucleotides as music of light with allowed 64 chords defining what I have called bio-harmony is essential for the resonance [L45, L46, L43](see `http://tinyurl.com/ydhxen4g`, `http://tinyurl.com/yd5t82gq`, and `http://tinyurl.com/y9jxyjns`). The 3 frequencies must be identical in the resonance: this is like turning 3 knobs in radio. This 3-fold resonance would correspond to the analytic mode. The second mode could be holistic in the sense that it would involve only the sum only the sum of the 3 frequencies modulo octave equivalence assigning a melody to a sequence of 3-chords.

2. The proposal is that amino-acids having no triplet decomposition are holistic and couple to the sum of 3 frequencies assignable to tRNA and mRNA in this manner. Also the RNAs in tRNA could couple to mRNA in this manner. One could perhaps say that tRNA, mRNA and amino-acids codons sing whereas DNA provides the accompaniment proceeding as 3-chords. The couplings of DNA nucleotides to RNA nucleotides would rely on the frequencies assignable to nucleotides.

3. If the sum of any 3 frequencies associated with mRNA codons is not the same except when the codons code for the same amino-acids, the representation of 3-chords with the sum of the notes is faithful. The frequencies to DNA and RNA nucleotides cannot be however independent of codons since the codons differing only by a permutation of letters would correspond to the same frequency and therefore code for the same amino-acid. Hence the information about the entire codon would be needed also in transcription and translation and could be provided either by dark DNA strand associated with DNA strand or by the interactions between the nucleotides of the DNA codon.

4. The DNA codon itself would know that it is associated with dark codon and the frequencies assignable to nucleotides could be determined by the dark DNA codon. It would be enough that the frequency of the letter depends on its position in the codon so that there would be 3 frequencies for every letter: 12 frequencies altogether.

   What puts bells ringing is that this the number of notes in 12-note scale for which the model of bio-harmony [L20, L45] (see `http://tinyurl.com/yad4tqwl` and `http://tinyurl.com/ydhxen4g`) based on the fusion of icosahedral (12 vertices and 20 triangular faces) and tetrahedral geometries by gluing icosahedron and tetrahedron along one face, provides a model as Hamiltonian cycle and produces genetic code as a by-product. Different Hamiltonian cycles define different harmonies identified as correlates for molecular moods.

   Does each DNA nucleotide respond to 3 different frequencies coding for its position in the codon and do the 4 nucleotides give rise to the 12 notes of 12-note scale? There are many choices for the triplets but a good guess is that the intervals between the notes of triplet are same and that fourth note added to the triplet would be the first one to realize octave equivalence. This gives uniquely $CEG\sharp$, $C\sharp FA$,$DF\sharp B\flat$, and $DG\sharp B$ as the triplets assignable to the nucleotides. The emergence of 12-note scale in this manner would be a new element in the model of bio-harmony.

   There are 4!=24 options for the correspondence between $\{A, T, C, G\}$ as the first letter and $\{C, C\sharp, D, D\sharp\}$. One can reduce this number by a simple argument.

(a) Letters and their conjugates form pyrimidine-purine pairs T, A and C, G. The square of conjugation is identity transformation. The replacement of note with note defining at distance of half-octave satisfies this condition (half-octave - tritonus - was a cursed interval in ancient music and the sound of ambulance realizes it). Conjugation could correspond to a transformation of 3-chords defined as

$$CEG\sharp \leftrightarrow DF\sharp B\flat \ , \quad C\sharp FA \leftrightarrow D\sharp GB \ .$$

(b) One could have

$$\{T,C\} \leftrightarrow \{CEG\sharp, C\sharp FA\} \ , \quad \{A,G\} \leftrightarrow \{DF\sharp B\flat, D\sharp GB\} \ ,$$
$$\text{or}$$
$$\{T,C\} \leftrightarrow \{DF\sharp B\flat, D\sharp GB\} \ , \quad \{A,G\} \leftrightarrow \{CEG\sharp, C\sharp FA\} \ .$$

.

(c) One can permute T and C and A and G in these correspondences. This leaves 8 alternative options. Fixing the order of the image of (T, C) to say $(C, C\sharp)$ fixes the order of the image of (A, G) to $(D, D\sharp)$ by the half-octave conjugation. This leaves 4 choices. Given the bio-harmony and having chosen one of these 4 options one could therefore check what given DNA sequence sounds as a sequence of 3-chords [L20].

That the position the frequency associated with the nucleotide depends on its position in the codon would also reflect the biochemistry of the codon and this kind of dependence would be natural. In particular, different frequencies associated with the first and third codon would reflect the parity breaking defining orientation for DNA.

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 [L36, L37]. In the recent view of quantum TGD [L89], both notions reduce to physics as number theory vision, which relies on $M^8 - H$ duality [L57, L58] and is complementary to the physics as geometry vision.

Zero energy ontology (ZEO) [L56] [K113] 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) [L56, L71] [K113] 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 [A14] 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 $z^i \to exp(i\alpha)z^i$ on the sphere S^5: $\sum z^i \bar{z}^i = R^2$. The metric of CP_2 is obtained by projecting the metric of S^5 orthogonally to the orbits of the isometries. Therefore the distance between the points of CP_2 is that between the representative orbits on S^5.

The line element has the following form in the complex coordinates

$$ds^2 = g_{a\bar{b}} d\xi^a d\bar{\xi}^b \ , \tag{A-2.4}$$

where the Hermitian, in fact Kähler metric $g_{a\bar{b}}$ is defined by

$$g_{a\bar{b}} = R^2 \partial_a \partial_{\bar{b}} K \ , \tag{A-2.5}$$

where the function K, Kähler function, is defined as

$$\begin{aligned} K &= log(F) \ , \\ F &= 1 + r^2 \ . \end{aligned} \tag{A-2.6}$$

The Kähler function for S^2 has the same form. It gives the S^2 metric $dzd\bar{z}/(1+r^2)^2$ related to its standard form in spherical coordinates by the coordinate transformation $(r, \phi) = (tan(\theta/2), \phi)$.

The representation of the CP_2 metric is deducible from S^5 metric is obtained by putting the angle coordinate of a geodesic sphere constant in it and is given

$$\frac{ds^2}{R^2} = \frac{(dr^2 + r^2\sigma_3^2)}{F^2} + \frac{r^2(\sigma_1^2 + \sigma_2^2)}{F} \ , \tag{A-2.7}$$

where the quantities σ_i are defined as

$$\begin{aligned} r^2\sigma_1 &= Im(\xi^1 d\xi^2 - \xi^2 d\xi^1) \ , \\ r^2\sigma_2 &= -Re(\xi^1 d\xi^2 - \xi^2 d\xi^1) \ , \\ r^2\sigma_3 &= -Im(\xi^1 d\bar{\xi}^1 + \xi^2 d\bar{\xi}^2) \ . \end{aligned} \tag{A-2.8}$$

R denotes the radius of the geodesic circle of CP_2. The vierbein forms, which satisfy the defining relation

$$s_{kl} = R^2 \sum_A e_k^A e_l^A \ , \tag{A-2.9}$$

are given by

$$\begin{aligned} e^0 &= \frac{dr}{F} \ , \quad e^1 = \frac{r\sigma_1}{\sqrt{F}} \ , \\ e^2 &= \frac{r\sigma_2}{\sqrt{F}} \ , \quad e^3 = \frac{r\sigma_3}{F} \ . \end{aligned} \tag{A-2.10}$$

The explicit representations of vierbein vectors are given by

$$\begin{aligned} e^0 &= \frac{dr}{F} \ , & e^1 &= \frac{r(sin\Theta cos\Psi d\Phi + sin\Psi d\Theta)}{2\sqrt{F}} \ , \\ e^2 &= \frac{r(sin\Theta sin\Psi d\Phi - cos\Psi d\Theta)}{2\sqrt{F}} \ , & e^3 &= \frac{r(d\Psi + cos\Theta d\Phi)}{2F} \ . \end{aligned} \tag{A-2.11}$$

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

$$\begin{aligned} V_{01} &= -\frac{e^1}{r} \ , & V_{23} &= \frac{e^1}{r} \ , \\ V_{02} &= -\frac{e^2}{r} \ , & V_{31} &= \frac{e^2}{r} \ , \\ V_{03} &= (r - \frac{1}{r})e^3 \ , & V_{12} &= (2r + \frac{1}{r})e^3 \ . \end{aligned} \tag{A-2.14}$$

The representation of the covariantly constant curvature tensor is given by

$$\begin{aligned} R_{01} &= e^0 \wedge e^1 - e^2 \wedge e^3 \ , & R_{23} &= e^0 \wedge e^1 - e^2 \wedge e^3 \ , \\ R_{02} &= e^0 \wedge e^2 - e^3 \wedge e^1 \ , & R_{31} &= -e^0 \wedge e^2 + e^3 \wedge e^1 \ , \\ R_{03} &= 4e^0 \wedge e^3 + 2e^1 \wedge e^2 \ , & R_{12} &= 2e^0 \wedge e^3 + 4e^1 \wedge e^2 \ . \end{aligned} \tag{A-2.15}$$

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 [A28] a general characterization of the geodesic sub-manifolds for an arbitrary symmetric space G/H is given. Geodesic sub-manifolds are in 1-1-correspondence with the so called Lie triple systems of the Lie-algebra g of the group G. The Lie triple system t is defined as a subspace of g characterized by the closedness property with respect to double commutation

$$[X,[Y,Z]] \in t \ \text{ for } \ X,Y,Z \in t \ . \tag{A-2.22}$$

$SU(3)$ allows, besides geodesic lines, two nonequivalent (not isometry related) geodesic spheres. This is understood by observing that $SU(3)$ allows two nonequivalent $SU(2)$ algebras corresponding to subgroups $SO(3)$ (orthogonal 3×3 matrices) and the usual isospin group $SU(2)$. By taking any subset of two generators from these algebras, one obtains a Lie triple system and by exponentiating this system, one obtains a 2-dimensional geodesic sub-manifold of CP_2.

Standard representatives for the geodesic spheres of CP_2 are given by the equations

$$S^2_I \ : \ \xi^1 = \bar{\xi}^2 \ \text{ or equivalently } \ (\Theta = \pi/2, \Psi = 0) \ ,$$

$$S^2_{II} \ : \ \xi^1 = \xi^2 \ \text{ or equivalently } \ (\Theta = \pi/2, \Phi = 0) \ .$$

The non-equivalence of these sub-manifolds is clear from the fact that isometries act as holomorphic transformations in CP_2. The vanishing of the second fundamental form is also easy to verify. The first geodesic manifold is homologically trivial: in fact, the induced Kähler form vanishes identically for S^2_I. S^2_{II} is homologically nontrivial and the flux of the Kähler form gives its homology equivalence class.

A-2.2 CP_2 geometry and Standard Model symmetries

Identification of the electro-weak couplings

The delicacies of the spinor structure of CP_2 make it a unique candidate for space S. First, the coupling of the spinors to the $U(1)$ gauge potential defined by the Kähler structure provides the missing $U(1)$ factor in the gauge group. Secondly, it is possible to couple different H-chiralities independently to a half odd multiple of the Kähler potential. Thus the hopes of obtaining a correct spectrum for the electromagnetic charge are considerable. In the following it will be demonstrated that the couplings of the induced spinor connection are indeed those of the GWS model [B36] 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

$$\begin{array}{lll} I_L^1 & = & \frac{(\Sigma_{01} - \Sigma_{23})}{2} \ , \\ I_L^2 & = & \frac{(\Sigma_{02} - \Sigma_{13})}{2} \ . \end{array} \tag{A-2.28}$$

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.

$$\begin{aligned} W_{03} = W_{12} \equiv 2I_3 = 2(e^0 \wedge e^3 + e^1 \wedge e^2) \ , \\ W_{01} = W_{23} \equiv I_1 = -e^0 \wedge e^1 - e^2 \wedge e^3 \ , \\ W_{02} = W_{31} \equiv I_2 = -e^0 \wedge e^2 - e^3 \wedge e^1 \ . \end{aligned} \tag{A-2.31}$$

The charged part of the Weyl tensor is right-handed and that the relative sign of the two terms in the curvature tensor and Weyl tensor are opposite.

Consider next the identification of the neutral gauge bosons γ and Z^0 as appropriate linear combinations of the two functionally independent quantities

$$\begin{aligned} X &= re^3 \ , \\ Y &= \frac{e^3}{r} \ , \end{aligned} \tag{A-2.32}$$

appearing in the neutral part of the spinor connection. We show first that the mere requirement that photon couples vectorially implies the basic coupling structure of the GWS model leaving only the value of Weinberg angle undetermined.

To begin with let us define

$$\begin{aligned} \bar{\gamma} &= aX + bY \ , \\ \bar{Z}^0 &= cX + dY \ , \end{aligned} \tag{A-2.33}$$

where the normalization condition

$$ad - bc = 1 \ ,$$

is satisfied. The physical fields γ and Z^0 are related to $\bar{\gamma}$ and $\bar{Z}^0$ by simple normalization factors.

Expressing the neutral part of the spinor connection in term of these fields one obtains

$$\begin{aligned} A_{nc} &= [(c+d)2\Sigma_{03} + (2d-c)2\Sigma_{12} + d(n_+1_+ + n_-1_-)]\bar{\gamma} \\ &+ [(a-b)2\Sigma_{03} + (a-2b)2\Sigma_{12} - b(n_+1_+ + n_-1_-)]\bar{Z}^0 \ . \end{aligned} \tag{A-2.34}$$

Identifying Σ_{12} and $\Sigma_{03} = 1 \times \gamma_5\Sigma_{12}$ as vectorial and axial Lie-algebra generators, respectively, the requirement that γ couples vectorially leads to the condition

$$c = -d \ . \tag{A-2.35}$$

Using this result plus previous equations, one obtains for the neutral part of the connection the expression

$$A_{nc} = \gamma Q_{em} + Z^0(I_L^3 - sin^2\theta_W Q_{em}) \ . \tag{A-2.36}$$

Here the electromagnetic charge Q_{em} and the weak isospin are defined by

$$\begin{aligned} Q_{em} &= \Sigma^{12} + \frac{(n_+1_+ + n_-1_-)}{6} \ , \\ I_L^3 &= \frac{(\Sigma^{12} - \Sigma^{03})}{2} \ . \end{aligned} \tag{A-2.37}$$

The fields γ and Z^0 are defined via the relations

$$\begin{aligned} \gamma &= 6d\bar{\gamma} = \frac{6}{(a+b)}(aX + bY) \ , \\ Z^0 &= 4(a+b)\bar{Z}^0 = 4(X - Y) \ . \end{aligned} \tag{A-2.38}$$

The value of the Weinberg angle is given by

$$sin^2\theta_W = \frac{3b}{2(a+b)} \ , \tag{A-2.39}$$

and is not fixed completely. Observe that right handed neutrinos decouple completely from the electro-weak interactions.

The determination of the value of the Weinberg angle is a dynamical problem. The original approach was based on the assumption that it makes sense to talk about electroweak action defined at fundamental level and introduce a symmetry breaking by adding an additional term proportional to Kähler action. The recent view is that Kähler action plus volume term defines the fundamental action.

The Weinberg angle is completely fixed if one requires that the electroweak action contains no cross term of type γZ^0. This leads to a definite value for the Weinberg angle.

One can however add a symmetry breaking term proportional to Kähler action and this changes the value of the Weinberg angle. As a matter fact, color gauge action identifying color gauge field as proportional to $H^A J_{\alpha\beta}$ is proportional to Kähler action. A possible interpretation would be as a sum of electroweak and color gauge interactions.

To evaluate the value of the Weinberg angle one can express the neutral part F_{nc} of the induced gauge field as

$$F_{nc} = 2R_{03}\Sigma^{03} + 2R_{12}\Sigma^{12} + J(n_+ 1_+ + n_- 1_-) \ , \tag{A-2.40}$$

where one has

$$\begin{aligned} R_{03} &= 2(2e^0 \wedge e^3 + e^1 \wedge e^2) \ , \\ R_{12} &= 2(e^0 \wedge e^3 + 2e^1 \wedge e^2) \ , \\ J &= 2(e^0 \wedge e^3 + e^1 \wedge e^2) \ , \end{aligned} \tag{A-2.41}$$

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

$$F_{nc} = \gamma Q_{em} + Z^0(I_L^3 - sin^2\theta_W Q_{em}) \ . \tag{A-2.42}$$

Evaluating the expressions above, one obtains for γ and Z^0 the expressions

$$\begin{aligned} \gamma &= 3J - sin^2\theta_W R_{12} \ , \\ Z^0 &= 2R_{03} \ . \end{aligned} \tag{A-2.43}$$

For the Kähler field one obtains

$$J = \frac{1}{3}(\gamma + sin^2\theta_W Z^0) \ . \tag{A-2.44}$$

Expressing the neutral part of the symmetry broken YM action

$$\begin{aligned} L_{ew} &= L_{sym} + f J^{\alpha\beta} J_{\alpha\beta} \ , \\ L_{sym} &= \frac{1}{4g^2} Tr(F^{\alpha\beta} F_{\alpha\beta}) \ , \end{aligned} \tag{A-2.45}$$

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 [B11]. The experimental value at the scale length scale of the electron can be deduced from the ratio of W and Z boson masses as $sin^2\theta_W = 1 - (m_W/m_Z)^2 \simeq .22290$. This ratio and also the weak boson masses depend on the length scale.

If one interprets the additional term proportional to J as color action, one could perhaps interpret the value of Weinberg angle as expressing a connection between strong and weak coupling constant evolution. The limit $f \to 0$ should correspond to an infinite value of color coupling strength and at this limit one would have $sin^2\theta_W = \frac{9}{28}$ for $f/g^2 \to 0$. This does not make sense since the Weinberg angle is in the standard model much smaller in QCD scale Λ corresponding roughly to pion mass scale. The Weinberg angle is in principle predicted by the p-adic coupling constant evolution fixed by the number theoretical vision of TGD.

One could however have a sum of electroweak action, correction terms changing the value of Weinberg angle, and color action and coupling constant evolution could be understood in terms of the coupling parameters involved.

Electroweak symmetry breaking

One of the hardest challenges in the development of the TGD based view of weak symmetry breaking was the fact that classical field equations allow space-time surfaces with finite but arbitrarily large size. For a fixed space-time surface, the induced gauge fields, including classical weak fields, are long ranged. On the other hand, the large mass for weak bosons would require a short correlation length. How can one understand this together with the fact that a photon has a long correlation length?

In zero energy ontology quantum states are superpositions of space-time surfaces as analogs of almost unique Bohr orbits of particles identified as 3-D surfaces. For some reason the superposition should be such that the quantum averages of weak gauge boson fields vanish below the weak scale whereas the quantum average of electromagnetic fields is non-vanishing.

This is indeed the case.

1. The supersymplectic symmetries form isometries of the world of classical worlds (WCW) and they act in CP_2 degrees of freedom as symplectic transformations leaving the CP_2 symplectic form J invariant and therefore also its contribution to the electromagnetic field since this part is the same for all space-time surfaces in the superposition of space-time surfaces as a representation of supersymplectic isometry group (as a special case a representation of color group).

2. In TGD, color and electroweak symmetries acting as holonomies are not independent and for the $SU(2)_L$ part of induced spinor connection the symplectic transformations induces $SU(2)_L \times U(1)_R$ gauge transformation. This suggests that the quantum expectations of the induced weak fields over the space-time surfaces vanish above the quantum coherence scale. The averages of W and of the left handed part of Z^0 should therefore vanish.

3. $\langle Z^0 \rangle$ should vanish. For $U(1)_R$ part of Z^0, the action of gauge transformation is trivial in gauge theory. Now however the space-time surface changes under symplectic transformations and this could make the average of the right-handed part of Z^0 vanishing. The vanishing of the average of the axial part of the Z^0 is suggested by the partially conserved axial current hypothesis.

One can formulate this picture quantitatively.

1. The electromagnetic field [L94] contains, besides the induced Kähler form, also the induced curvature form R_{12}, which couples vectorially. Conserved vector current hypothesis suggests that the average of R_{12} is non-vanishing. One can express the neutral part of the induced gauge field in terms of induced spinor curvature and Kähler form J as

$$\begin{aligned} R_{03} &= 2(2e^0 \wedge e^3 + e^1 \wedge e^2) = J + 2e^0 \wedge e^3 \ , \\ J &= 2(e^0 \wedge e^3 + e^1 \wedge e^2) \ , \\ R_{12} &= 2(e^0 \wedge e^3 + 2e^1 \wedge e^2) = 3J - 2e^0 \wedge e^3 \ , \end{aligned} \tag{A-2.50}$$

2. The induced fields γ and Z^0 (photon and Z- boson) can be expressed as

$$\begin{aligned} \gamma &= 3J - sin^2\theta_W R_{12} \ , \\ Z^0 &= 2R_{03} = 2(J + 2e^0 \wedge e^3) \end{aligned} \tag{A-2.51}$$

$$per. \tag{A-2.52}$$

The condition $\langle Z^0 \rangle = 0$ gives $2\langle e^0 \wedge e^3 \rangle = -2J$ and this in turn gives $\langle R_{12} \rangle = 4J$. The average over γ would be

$$\langle \gamma \rangle = (3 - 4sin^2\theta_W)J \ .$$

For $sin^2\theta_W = 3/4$ $langle\gamma\rangle$ 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 [B12] .

   The action of the reflection P on spinors of is given by

$$\Psi \rightarrow P\Psi = \gamma^0 \otimes \gamma^0 \Psi \ . \tag{A-2.53}$$

in the representation of the gamma matrices for which γ^0 is diagonal. It should be noticed that W and Z^0 bosons break parity symmetry as they should since their charge matrices do not commute with the matrix of P.

The guess that a complex conjugation in CP_2 is associated with T transformation of the physicist turns out to be correct. One can verify by a direct calculation that pure Dirac action is invariant under T realized according to

$$\begin{aligned} m^k &\rightarrow T(M^k) \ , \\ \xi^k &\rightarrow \bar{\xi}^k \ , \\ \Psi &\rightarrow \gamma^1\gamma^3 \otimes 1\Psi \ . \end{aligned} \tag{A-2.54}$$

The operation bearing closest resemblance to the ordinary charge conjugation corresponds geometrically to complex conjugation in CP_2:

$$\begin{aligned} \xi^k &\rightarrow \bar{\xi}^k \ , \\ \Psi &\rightarrow \Psi^\dagger \gamma^2\gamma^0 \otimes 1 \ . \end{aligned} \tag{A-2.55}$$

As one might have expected symmetries CP and T are exact symmetries of the pure Dirac action.

A-3 Induction procedure and many-sheeted space-time

Since the classical gauge fields are closely related in TGD framework, it is not possible to have space-time sheets carrying only single kind of gauge field. For instance, em fields are accompanied by Z^0 fields for extremals of Kähler action.

Classical em fields are always accompanied by Z^0 field and some components of color gauge field. For extremals having homologically non-trivial sphere as a CP_2 projection em and Z^0 fields are the only non-vanishing electroweak gauge fields. For homologically trivial sphere only W fields are non-vanishing. Color rotations does not affect the situation.

For vacuum extremals all electro-weak gauge fields are in general non-vanishing although the net gauge field has U(1) holonomy by 2-dimensionality of the CP_2 projection. Color gauge field has $U(1)$ holonomy for all space-time surfaces and quantum classical correspondence suggest a weak form of color confinement meaning that physical states correspond to color neutral members of color multiplets.

A-3.1 Induction procedure for gauge fields and spinor connection

Induction procedure for gauge potentials and spinor structure is a standard procedure of bundle theory. If one has embedding of some manifold to the base space of a bundle, the bundle structure can be induced so that it has as a base space the imbedded manifold, whose points have as fiber the fiber if embedding space at their image points. In the recent case the embedding of space-time surface to embedding space defines the induction procedure. The induced gauge potentials and gauge fields are projections of the spinor connection of the embedding space to the space-time surface (see `http://tgdtheory.fi/appfigures/induct.jpg`).

Induction procedure makes sense also for the spinor fields of embedding space and one obtains geometrization of both electroweak gauge potentials and of spinors. The new element is induction of gamma matrices which gives their projections at space-time surface.

As a matter fact, the induced gamma matrices cannot appear in the counterpart of massless Dirac equation. To achieve super-symmetry, Dirac action must be replaced with Kähler-Dirac action for which gamma matrices are contractions of the canonical momentum currents of Kähler action with embedding space gamma matrices. Induced gamma matrices in Dirac action would correspond to 4-volume as action.

Fig. 9. Induction of spinor connection and metric as projection to the space-time surface. `http://tgdtheory.fi/appfigures/induct.jpg`.

A-3.2 Induced gauge fields for space-times for which CP_2 projection is a geodesic sphere

If one requires that space-time surface is an extremal of Kähler action and has a 2-dimensional CP_2 projection, only vacuum extremals and space-time surfaces for which CP_2 projection is a geodesic sphere, are allowed. Homologically non-trivial geodesic sphere correspond to vanishing W fields and homologically non-trivial sphere to non-vanishing W fields but vanishing γ and Z^0. This can be verified by explicit examples.

$r = \infty$ surface gives rise to a homologically non-trivial geodesic sphere for which e_0 and e_3 vanish imply the vanishing of W field. For space-time sheets for which CP_2 projection is $r = \infty$ homologically non-trivial geodesic sphere of CP_2 one has

$$\gamma = (\frac{3}{4} - \frac{sin^2(\theta_W)}{2})Z^0 \simeq \frac{5Z^0}{8} \quad .$$

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 [K49, K27, K86] [L74, L89].

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 superconformal invariance behave like "short" strings with length scale given by CP_2 size, which is 10^4 times longer than Planck scale characterizing strings in string models.

2. Wormhole contact defines basic stringy interaction vertex for fermion-fermion scattering. The propagator is essentially the inverse of the superconformal scaling generator L_0. Wormhole contacts containing fermion and antifermion at its opposite throats behave like virtual bosons so that one has BFF type vertices typically.

3. In topological sense one has 3-vertices serving as generalizations of 3-vertices of Feynman diagrams. In these vertices 4-D "lines" of generalized Feynman diagrams meet along their 3-D ends. One obtains also the analogs of stringy diagrams but stringy vertices do not have the usual interpretation in terms of particle decays but in terms of propagation of particles along two different routes.

Fig. 8. a) TGD analogs of Feynman and string diagrammatics at the level of 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 [K49, K86].

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 [L39] [L74, L76, L77] 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 [L89]. 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 [L89] 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 [L89] 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 [L89] 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 [L80] 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 [K61, K62]). 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 [L80], 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 [L80], 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 [L80].

3. p-Adic length scale hypothesis [L90] 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 [L89] 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 $\delta M^4_+ \times CP_2$ [K49, K27]. 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 [L85].

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 [K65, K57, K24]. The fusion of the various p-adic physics leads to what I call adelic physics [L36, L37]. Later the hypothesis about hierarchy of Planck constants labelling phases of ordinary matter behaving like dark matter emerged [K29, K30, K31, K31].

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 [L57, L58] 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 [L80, L85]. 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 [L39] 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 [A7]. p-Adic numbers are representable as power expansion of the prime number p of form

$$x = \sum_{k \geq k_0} x(k) p^k, \; x(k) = 0, ..., p-1 \; . \tag{A-6.1}$$

The norm of a p-adic number is given by

$$|x| \;=\; p^{-k_0(x)} \;. \tag{A-6.2}$$

Here $k_0(x)$ is the lowest power in the expansion of the p-adic number. The norm differs drastically from the norm of the ordinary real numbers since it depends on the lowest pinary digit of the p-adic number only. Arbitrarily high powers in the expansion are possible since the norm of the p-adic number is finite also for numbers, which are infinite with respect to the ordinary norm. A convenient representation for p-adic numbers is in the form

$$x \;=\; p^{k_0}\varepsilon(x) \;, \tag{A-6.3}$$

where $\varepsilon(x) = k + ...$ with $0 < k < p$, is p-adic number with unit norm and analogous to the phase factor $exp(i\phi)$ of a complex number.

The distance function $d(x,y) = |x-y|_p$ defined by the p-adic norm possesses a very general property called ultra-metricity:

$$d(x,z) \;\leq\; max\{d(x,y), d(y,z)\} \;. \tag{A-6.4}$$

The properties of the distance function make it possible to decompose R_p into a union of disjoint sets using the criterion that x and y belong to same class if the distance between x and y satisfies the condition

$$d(x,y) \;\leq\; D \;. \tag{A-6.5}$$

This division of the metric space into classes has following properties:

1. Distances between the members of two different classes X and Y do not depend on the choice of points x and y inside classes. One can therefore speak about distance function between classes.

2. Distances of points x and y inside single class are smaller than distances between different classes.

3. Classes form a hierarchical tree.

Notice that the concept of the ultra-metricity emerged in physics from the models for spin glasses and is believed to have also applications in biology [B31]. The emergence of p-adic topology as the topology of the effective space-time would make ultra-metricity property basic feature of physics.

Canonical correspondence between p-adic and real numbers

The basic challenge encountered by p-adic physicist is how to map the predictions of the p-adic physics to real numbers. p-Adic probabilities provide a basic example in this respect. Identification via common rationals and canonical identification and its variants have turned out to play a key role in this respect.

1. Basic form of the canonical identification

There exists a natural continuous map $I : R_p \to R_+$ from p-adic numbers to non-negative real numbers given by the "pinary" expansion of the real number for $x \in R$ and $y \in R_p$ this correspondence reads

$$\begin{aligned} y \;&=\; \sum_{k>N} y_k p^k \to x = \sum_{k<N} y_k p^{-k} \;, \\ y_k \;&\in\; \{0,1,..,p-1\} \;. \end{aligned} \tag{A-6.6}$$

This map is continuous as one easily finds out. There is however a little difficulty associated with the definition of the inverse map since the pinary expansion like also decimal expansion is not unique ($1 = 0.999...$) for the real numbers x, which allow pinary expansion with finite number of pinary digits

$$\begin{aligned} x &= \sum_{k=N_0}^{N} x_k p^{-k} \ , \\ x &= \sum_{k=N_0}^{N-1} x_k p^{-k} + (x_N - 1)p^{-N} + (p-1)p^{-N-1} \sum_{k=0,..} p^{-k} \ . \end{aligned} \tag{A-6.7}$$

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 [L74] 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 $p^k \to m^k = \hbar_{eff} p^k/p^2$ conforming in spirit with UP but turned out to be too naive.

The improved form [L74] 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 [L74] 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 [L57, L58]. 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 $X^4 \subset M^8$ [L53]. 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 [L74]. 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 [L65] 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 [L74]. 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 [L56] [K113].

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 [L56].

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 [L51] in atomic scale can be explained by the same mechanism [L51]. 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 [J7] 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 [L52]. 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 [L55, L100].

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 [L55, L100]. 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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