Quantum Theory of Self-Organization

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Contents

Abstract

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

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

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

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

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

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

1 Introduction

Self-organization [B3] seems to be closely related to the generation of fractal patterns and the book of Barnsley [A5] about fractals gives rather convincing arguments supporting the belief that a very general class of fractals can be regarded as fixed points of iteration. The space in which fixed point exists is rather abstract: typically it belongs to the set of subsets of some space, say, 3-dimensional Euclidian space. This fixed point can be a landscape, biosystem, ecological population,

hydrodynamical flow,... For instance, the success of this recipe in reproducing even a virtual photo of a forest is amazing. Even evolution could be regarded as resulting from this kind of iterative process leading gradually to a fixed point.

One can even consider the possibility that iteration, if understood in a sufficiently general sense, could be the basic element of self-organization. There is no obvious manner how this iteration could result from the equations of the classical physics. For instance, Haken has been ready to consider the possibility that subsystems, even electron, are actually certain kind of computers, cellular automata and that the basic computational step would provide the required fundamental iteration step. Zero energy ontology assigns to electron fundamental time scale of.1 seconds, which is also a fundamental bio-rhythm so that this idea need not be so crazy as it looks first.

TGD suggests that the quantum jump between quantum histories could be the fundamental iteration step in very general sense of the world. This iteration would leave the other boundary of causal diamond to reduced state but change the state at the other boundary and also the average position of the other boundary. Self-organization would have a completely new meaning as the evolution of the hierarchical structures formed by conscious entities - selves. The iteration step could be seen reaction of self to its state created in previous quantum jump involving also the interaction with external world essential for self-organization.

The recent progress in understanding of how experienced time and its arrow emerge in Zero Energy Ontology (ZEO) allows to have a more concrete view about how the iterative aspect of quantum self-organization emerges.

1. State function reduction can occur at the upper or lower boundary of causal diamond CD and can do so repeatedly: this gives rise to a definite arrow of time, which changes when the boundary where reduction takes place, changes.

2. Let us assume that lower boundary to which we assign positive energy part of the state is the boundary where reductions occur. One can write the zero energy state as a superposition of products of positive and negative energy states associated with the two boundaries.

3. As in standard quantum measurement theory, repeated state function reductions to the lower boundary of CD leave the positive energy parts of thestates with same quantum numbers invariant. At opposite boundary the non-triviality of M-matrix means that corresponding part of the state changes and product state is replaced with superposition of products with same positive energy part.

4. Even de-localization in moduli space of CDs with fixed lower boundary can occur: the position of upper tip characterized by the tip-tip proper time distance from lower boundary and discrete Lorentz boost leaving the lower boundary invariant can take place. Dispersion analogous to that for Schrödinger equation takes place, and the average temporal distance between tips increases: this corresponds to the experience about a flow and arrow of time. Self can be identified as the sequence of quantum jumps performing state function reduction at fixed boundary of CD. The state function reductions clearly act like iteration. If repeated sufficiently many times state function reduction can lead to a fixed point or limit cycle and statistical variant of chaos theory can result as outcome.

Quantum jump decomposes to quantum jumps performed by separate selves with self being defined as subsystem able to remain unentangled during sequential quantum jumps. State function reduction part of quantum jump corresponds to the measurement of density matrix for some subsystem of self (or equivalently, for its complement inside self). If each quantum jump involves localization in zero modes representing classical degrees of freedom entangled with quantal degrees of freedom within accuracy defined by the measurement resolution, the final states of quantum jumps are superpositions of macroscopically equivalent space-time surfaces. This would explain the classicality of the world of the subjective experience.

Negentropy Maximization Principle (NMP) states that in a given quantum state only one of the most quantum entangled subsystems can perform the quantum jump. The reduction of the entanglement entropy in the quantum jump is as large as possible: presumably the interpretation of entanglement entropy as some kind of information gain makes sense [K4]. Quantum jumps inside self imply dissipation crucial for self organization and quantum jump could be regarded as

the basic step of iteration process. If self consists of a large number of nearly identical sub-selves, quantum statistical determinism implies that quantum jump can be interpreted as iterated map from the point of view of self. From the point of view of entire Universe this is certainly the case. NMP predicts that self organization and hence presumably also fractalization can occur inside selves.

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

With respect to geometric time the contents of conscious experiences is naturally determined by the space-time region inside CD in zero energy ontology. This geometro-temporal integration should have subjecto-temporal counterpart. The experiences of self are determined by the mental images assignable to sub-selves (having sub-CDs as imbedding space correlates) and the quantum jump sequences associated with sub-selves define a sequence of mental images. The hypothesis is that self experiences these sequences of mental images as a continuous time flow. In absence of mental images self would have experience of "timelessness" in accordance with the reports of practitioners of various spiritual practices. Self would lose consciousness in quantum jump generating entropic entanglement and experience enlightment if the resulting entanglement is negentropic. The assumption that the integration of experiences of self involves a kind of averaging over sub-selves of sub-selves guarantees that the sensory experiences are reliable despite the fact that quantum nondeterminism is involved with each quantum jump.

Thus the measurement of density matrix defined by the $MM^\dagger$, where M is the M-matrix between positive and negative energy parts of the zero energy state would correspond to the passive aspects of consciousness such as sensory experiencing. U would represent at the fundamental level volition as a creation of a quantum superposition of possibilities. What follows it would be a selection between them. The choice between different maxima of Kähler function could be basically responsible for the active aspect of consciousness. The fundamental perception-reaction feedback loop of biosystems would result from the combination of the active and passive aspects of consciousness represented by U and M.

TGD indeed gives good hopes for understanding self-organization using quantum level concepts.

1. Quantum criticality of TGD suggests the existence of macroscopic quantum systems in all length scales so that quantum theory of self-organization might apply also in the description of the hydrodynamical self-organization. The proposed interpretation of dark matter in terms of a hierarchy of Planck constants requiring a generalization of the notion of imbedding space to a book like structure with pages characterized partially by the value of Planck constant leads to a similar prediction [K10]. On basis of some intriguing findings about planetary orbits the space-time sheets mediating gravitational interaction are proposed to have gigantic values of Planck constant: the mysterious dark energy would corresponds to macroscopic quantum systems in astrophysical and even cosmic length and time scales [K29].

   The recent understanding of quantum criticality leads to a general vision about life as an attempt to stay at quantum criticality (homeostasis) while phase transitions reducing criticality and increasing the value of Planck constants and increasing negentropic resources of the system tend to occur spontaneously. This vision is reminiscent of the vision of Eastern philosophies involving the notions of Karma, ego, and "Let go".

2. Both p-adic length scale hierarchy and hierarchy of Planck constants suggest that evolution can be seen as a dispersion or migration like process in the world of classical worlds whose

sectors correspond CDs characterized by the positions of their tips, by the p-adic length scales characterizing the light-like 3-surfaces and also by the sizes of corresponding CDs as well as the page of the Big Book labelled by the value of Planck constant. Since the number of primes larger than given prime is infinite, one expects that p must increase in the long run. This would mean that the p-adic primes characterizing given light-like 3-surfaces tend to increase meaning also the increase of the size of the surface. A possible interpretation is in terms of cosmic expansion. Also NMP favours the increase of p and implies evolution and second law of thermodynamics since maximum entanglement entropy equal to maximum negentropy gain in quantum jump increases with p. The phase transitions increasing the value of Planck constant involve tunnelling between the pages of the book like structure defined by the imbedding space, and generate quantum coherent space-time regions with increasing size. They would give rise to similar evolution. A possible interpretation is as a counterpart of quantum counterpart of cosmic evolution reduced to a sequence of phase transitions. These periods would correspond to accelerated cosmic expansion difficult to understand in standard cosmology. The model of EEG would be one concrete application of this vision. An open question is whether the two expansion like evolutions are independent or whether there is some connection between them.

3. The replacement of the point like particle with 3-surface brings in an infinite number of zero modes characterizing the shape and size of and the classical Kähler field (projection of CP_2 Kähler form) associated with the space-time surface $X^4(X^3)$ assignable to a given 3-surface X^3 having components at the boundaries of CD and its sub-CDs. Even macroscopic 3-surfaces behave like elementary particles in these degrees of freedom. These zero modes serve as fundamental order parameters, which in the ordinary theories of self-organization must be introduced in an ad hoc manner. As already noticed, localization in the zero modes within measurement resolution implies that the world of conscious experience looks classical and that time evolution in zero modes can be regarded as hopping like motion.

4. Long range quantum correlations are crucial for quantum self-organization. Quantum criticality is indeed basic aspect of quantum TGD. The preferred extremals of Kähler action having interpretation as generalized Bohr orbits are critical in the sense that there exist deformations of the space-time surface -actually infinite number of them- for which the second variation of Kähler action vanishes. The hierarchy of Planck constants implies the criticality against phase transitions changing the value of Planck constant and realized as a tunnelling between the pages of the "Big Book" [K10]. This has many implications. Quantum criticality is characterized by long range quantum correlations and implies also fractality. The universality of $1/f$ noise, which is a direct consequence of criticality, is difficult to understand in standard physics context since critical systems are by definition unstable. Therefore the universality of $1/f$ noise could be seen as a direct support for quantum criticality of the entire Universe. From the real point of view self itself is a critical phenomenon. The exact vanishing of entanglement with external world is extremely improbable and must be replaced with the vanishing of entanglement modulo finite measurement resolution. If one accepts the notion of number theoretic Shannon entropy, entanglement can be negentropic and instead of a loss of consciousness leads to kind of enlightment experience. Also in this case the criticality is present since entanglement probabilities are not in general rational nor even algebraic.

5. Arbitrarily large join along boundaries condensates of 3-surfaces are possible by quantum criticality and this suggests the possibility of arbitrarily large macroscopic quantum subsystems. Especially interesting biological examples of join along boundaries bonds are chemical bonds, the MAPs connecting microtubules and gap junctions connecting cells. Join along boundaries bonds can also join mind-like space-time sheets.

6. The many-sheeted space-time concept having hierarchical structure provides the realization of a fundamental slaving hierarchy at the level of the space-time geometry. p-Adic length scale hierarchy and the hierarchy of Planck constant make this hypothesis quantitative.

7. Spin glass analogy leads to an infinite-dimensional generalization of Thom's catastrophe theory and the maxima of Kähler function play the role of the minima of the potential

function in Haken's theory of self-organization. Vacuum functional of TGD in turn is in the role of the generalized partition function appearing in Haken's theory.

8. Dissipation can be understood as caused by quantum jumps and occurs only inside selves. Dissipation leads to Darwinian selection of the asymptotic self-organization patterns and the selection of both genes and memes, in particular stable mental images, can be understood as resulting from quantum self-organization. Note that dissipation can be regarded as a direct signature of consciousness.

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

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

Rupert Sheldrake [I4] postulates the concept of morphic fields and morphic resonance making possible learning and memory at the level of species. The comparison with Rupert Sheldrake's concepts of morphic field and morphic resonance leads to interesting ideas about how learning at the level of species could occur quantum-mechanically. For instance, the phenomenon of biofeedback suggests that self could quite generally effectively act on its sub-selves. In zero energy ontology all quantum states have properties allowing to interpret them as memes or quanta of morphic fields and the challenge is to find their biological counterparts. DNA as topological quantum computer hypothesis suggest the identification of the biological memes as topological quantum computer programs assignable to the intronic portion of the genome and coded also by nerve pulse patterns. The notion of magnetic body as intentional agent leads to a concrete model for the morphic resonance as a transfer of topological quantum computation programs between separate brains with the mediation of the personal magnetic bodies and the magnetic body of Mother Gaia using EEG like communications. The recent view is that magnetic bodies in 4-D sense are the TGD counterparts of morphic fields serving as templetes for the self-organization of ordinary matter. The model explains also "alike likes alike" rule.

The appendix of the book gives a summary about basic concepts of TGD with illustrations. Pdf representation of same files serving as a kind of glossary can be found at `http://tgdtheory.fi/tgdglossary.pdf` [L3].

2 Quantum Theory Of Self-Organization

In the following basic ideas about self-organization and its quantum counterpart are introduced.

2.1 Basic Characteristics Of Self-Organization

Self organizing system corresponds typically to a system dissipating the energy fed into it. Dissipation leads to typical self-organization patterns decomposing into more or less autonomous subsystems. Subsystems perceive the state of the external world and reacts to it. Human society is a typical example in which individuals or groups of them perceive and react. Self-organization is also critical phenomenon in the sense that new self-organization patterns are formed in phase transition like manner at the critical values of the parameters characterizing the interaction of the system with external world. Co-operatitivity, long range correlations and fractality, typical characteristics of critical phenomena, are involved with the emergence of new self-organization patterns. Also spontaneous symmetry breaking associated with the phase transitions changing self-organization pattern is a characteristic of self-organization process.

Iteration, understood in a very general sense, seems to be the basic element of self-organization. A good example is provided by cellular automata (game of life is the best known example). Automaton consists of cells, which perceive their surroundings and perform a decision to change their state according to some rule. Rule need not be deterministic but the dynamics dictated by it is irreversible. This is what makes it so difficult to understand how iteration might result from the reversible equations of physics and suggests that thermodynamics or some deeper principle behind thermodynamics is important.

Second example is camera, which monitors tv screen to which the picture taken by the camera is the feedback. This system exhibits typical self-organization patterns obtained by varying the direction angle of the camera with respect to the TV screen. Iteration is rather abstract process now: camera perceives the state of tv and reacts by sending a new picture to the TV screen.

Benard convection is a third standard example of self-organization. When liquid is heated evenly from below, a temperature gradient develops and at some critical value of temperature gradient, convection sets on. A flow pattern consisting of liquid cells is formed. The size and shape of cell as well as the pattern of liquid motion in cell depends on the parameters characterizing the situation (size and shape of the liquid vessel, the temperature difference, ...). As temperature difference increases, more complicated flow patterns emerge: what happens is essentially that patterns of larger scale coherent motions emerge by the organization of the Benard cells to larger units.

Biosystems provide more complicated examples of self-organization. In this case self-organization has many hierarchical levels. First DNA and proteins together with genetic code are formed by self-organization at molecular level, then come monocellulars, multicellulars, ..., individuals, families, social organizations, ... Clearly, subsystems of previous level form combine to form larger coherent subsystems at the higher levels of self-organization. Here the basic interaction step is response to a response.

Iteration is clearly a "social" process: subsystem perceives consciously the external world and reacts to it. Subsystem can in principle be any subsystem of the entire system so that the scenario is considerably more general than cellular automaton. The process can also create a subsystem such as Benard cell in Benard convection or a cell in biological evolution.

2.2 Self-Organization As Organization Of Self-Hierarchies

TGD suggests that the quantum jump between quantum histories could be the fundamental iteration step of self-organinization with M-matrix related to the perception and U-process to the volitional act resulting as a reaction to the perception. Even more, self-organization has a completely new meaning in TGD. Self-organization can be identified as the evolution of hierarchical structures formed by conscious selves. Zero energy ontology, p-adic length scale hierarchy, and the hierarchy of Planck constants bring in additional refinements to the picture.

2.2.1 Quantum jump as the basic iterative step of self-organization

In TGD subjective time evolution corresponds to the sequence of quantum jumps

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

where U represents unitary quantum mechanical "time evolution".

Quantum jump corresponds to the measurement of density matrix for some subsystem of self (or equivalently, for its complement inside self). In quantum jump a localization in zero modes (possibly modulo measurement resolution) takes place and the final states of quantum jumps are superpositions of space-time surfaces indistinguishable in the measurement resolution used This would explain the classicality of the world of the subjective experience. Quantum jump occurs also between two classical histories, say between solutions of reversible equations of hydrodynamics in Benard convection.

In zero energy ontology the view about quantum state as quantum history finds a more precise quantitative characterization through the notion causal diamond (CD).

2.2.2 Autonomous subsystems of self-organized system as selves

A crucial concept is that of self being defined as a subsystem able to remain unentangled during sequential quantum jumps. Self would lose consciousness when it entangles. What this statement really means is far from obvious and I have proposed several interpretations.

1. The idea that even slightest entanglement leads to a loss of consciousness does not sound realistic. This suggests that entanglement should be defined only modulo finite measurement resolution. System would be conscious only provided that its entanglement entropy with the external world is below the value defined by the measurement resolution. For hyper-finite factors of type II_1 the notion of finite measurement resolution is unavoidable. The concrete interpretation at space-time level would be that space-time sheets (sub-selves) topologically condensed at larger space-time sheets (selves) can be connected by flux tubes to form an entangled state. The selves represented by the larger space-time sheets would remain unentangled in the resolution applying to the systems themselves (flux tubes would be invisible in this resolution). This invisible entanglement would however give rise to a sharing and fusion of mental images implying what might be called stereo consciousness.

2. How the notion measurement resolution should be defined is far from obvious. p-Adication approach suggests that finite measurement resolution boils down to a pinary cutoff for the p-adic entanglement entropy represented as a series in powers of p. This pinary cutoff should have also space-time correlate. For hyper-finite factors of type II_1 and type III_1 emerging naturally in quantum TGD entanglement entropy is always defined only modulo finite measurement resolution, which can be characterized in terms of inclusions of hyper-finite factors [K33]. The included factor defines the measurement resolution in the sense that its action creates states not distinguishable from the original in the resolution used. There should exist a connection between the two approaches.

3. A further complication is due to the fact that also the p-adic variants of Shannon entropy obtained by replacing the logarithm of probability with the logarithm of the p-adic norm of probability make sense if entanglement probabilities are rational or have values in some algebraic extension of rationals. The fact that number theoretic entanglement entropy can be negative it especially attractive from the point of view of consciousness theory and also quantum computation since entanglement indeed carries information. There is also a temptation to identify evolution as the emergence of increasingly complex systems having negative entanglement entropy. The generation of negative entanglement entropy could correspond to a kind of enlightenment experience-fusion to a sea of consciousness- instead of a loss of consciousness.

4. This forces to reconsider the original vision that everything is conscious but consciousness can be lost as the system entangles in U process. U process generates highly entangled states and the sub-sequent state function reduction (possibly modulo measurement resolution) repeatedly decomposes the Universe (or CD) into unentangled pairs of subsystems. The process stops for any subsystem for which all subsystem pairs have either bound state entanglement or negentropic entanglement (see **Fig.** `http://tgdtheory.fi/appfigures/cat.jpg` or **Fig. ??** in the appendix of this book). If the bound state entanglement is entropic, the entangled subsystems lose consciousness. If the entanglement beween the subsystems in negentropic the process stops but subsystems remain conscious. Mystics might associate the entropic entanglement to what they calls attachment and negentropic entanglement to a relationship which they might characterize as love.

5. Zero energy ontology brings in additional aspects. Zero energy states correspond to entangled pairs of positive and negative energy states located at the opposite light-like boundaries of a given causal diamond (CD) defined as the intersection of future and past directed light-cones. Strictly speaking a Cartesian product of CD with CP_2 is in question. CDs form a fractal hierarchy. In the ordinary ontology zero energy state corresponds to a physical event. The time-like entanglement between positive and negative energy states defines M-matrix generalizing the notion of S-matrix. Time-like entanglement must be fundamental also from

the point of view of consciousness as a reduction of quantum state to a state with well defined values of observables for the initial (positive energy) and final (negative energy) states.

The identification of the space-time correlates of selves is not so obvious as one might think. One can imagine three options. The space-time correlates of selves are space-time sheets or CDs or somehow combinations of these two.

1. If space-time sheets serve as correlates for selves, the space-time correlate for the entanglement is the presence of flux tubes connecting the space-time sheets serving as correlates for selves. The entanglement which corresponds to join along boundaries bonds associated with sub-selves (smaller space-time sheets topologically condensed at the space-time sheet representing self) is below the measurement resolution assignable to self. In this kind of situation selves remain conscious whereas sub-selves loose consciousness for positive entanglement entropy and fuse to form single stereo mental image of self. For negative entanglement entropy sub-selves would remain conscious.

2. In zero energy ontology [K5] one is forced to ask whether the notion of self should be defined at the level of imbedding space rather that at the level of space-time sheets so that a given CD would serve as a correlate for self. This identification leads to a beautiful argument for how the arrow of subjective time, the flow of subjective time, and the localization of the contents of conscious experience around a narrow time interval takes place [K2]. There is no reason for why CDs should not be allowed to overlap and this overlap would be a natural correlate for the sharing and fusion of mental images. Both of these identifications look natural and one can argue that the geometric correlates of self exist at both imbedding space and space-time level.

3. If both space-time sheets and CDs serve as correlates for selves, the join along boundaries bonds would connect space-time sheets associated with the two CDs and would belong to their intersection. One can also require that the CDs are at the same p-adic level of hierarchy. In other words, CDs correspond to the same value of p-adic prime near a power of two meaning that the temporal distance between the tips of CDs is same octave of CP_2 time for the standard value of Planck constant. The hierarchy of Planck constants [K10] means an additional complication in this picture but does not bring in anything essentially new.

One should also understand how the experience about the flow of subjective time emerges.

1. It seems obvious that quantum jumps must somehow integrate to self: quantum jump would be the elementary particle of consciousness and self the many particle state -possibly bound state (one can of course wonder what the notion of bound state means in case of zero energy states: can one say that positive and negative energy parts of the state form a bound state?) This analogy and the identification of zero energy states as events suggests that the notion of self could be reduced to that of quantum jumps so that self hierarchy would correspond to a hierarchy of quantum jumps within quantum jumps and also to the hierarchy of CDs within CDs.

2. The state function for the zero energy state should create the fundamental experience about time flow. The value of the time increment associated with the quantum jump would be determined by the temporal distance between the tips of CD and determine the interval about which the contents of consciousness is about. Note that for quantum states identified as time equal to constant snapshots quantum jump cannot give rise to an experience about flow of time since information about two values of geometric time is not present. Before zero energy ontology the proposed way out of this problem was the failure of classical determinism in the standard sense and zero energy ontology could be seen as a manner to formalize this failure.

3. The fractality of zero energy ontology implies that zero energy states are analogous to self-organization patterns and that a sequence of quantum jumps leads to an asymptotic self-organization pattern in 4-D sense. The M-matrix defining the generalization of S-matrix is indeed a "complex square root" of the density matrix so that statistical and thermodynamical aspects are present already at the fundamental level.

Since self behaves effectively like a separate autonomous universe, an attractive hypothesis is that the typical decomposition of self-organized system to almost autonomous subsystems corresponds to the decomposition of universe to selves. This means very close connection between self-organization theory and theory of consciousness.

1. The hierarchy of selves corresponds geometrically to the hierarchies of space-time sheets and CDs and defines obvious counterpart for the nested slaving hierarchies of self-organized systems with the property that the system at given level of hierarchy serves as a master for the lower level systems inside it. Zero energy ontology implies that physical state itself corresponds to a physical event is more like a process than state so that self-organization is basically evolution of temporal rather than spatial patterns. In neuroscience this has dramatic implications for the model of long term memories and also for the models of sensory perception and motor action.

2. Although active quantum jump itself is nondeterministic, quantum statistical determinism implies that the time evolution by quantum jumps is predictable at the limit of large self having large number of sub-selves. In this quantum evolution is a genuinely iterative process in the space of distribution functions for various types of selves with interaction step defined by state function reduction for zero energy state (perception) following by the volitional act representing the reaction creating a superposition of possibilities (U-process). At the level of the large sub-selves there is always non-predictability involved. This feature could make it possible to understand the special features of biological self-organization. A good example is the behavior of group of people who meet for the first time: self-organization leads rapidly to an adoption of simple social roles. In this kind of self organization both active and passive quantum jumps play important role.

3. If the notion of number theoretic entropies is accepted, the generation of larger quantum coherent structures by the generation of rational or algebraic entanglement is favored by NMP. This feature distinguishes quantum TGD from other quantum theoretic approaches to self-organization and could allow to understand the miracle like phenomena occurring in the evolution of the living matter. One can ask whether this process is always involved in the phase transitions generating larger coherent structures (also the increase of Planck constant and p-adic length scale could be involved).

2.3 Dissipation And Quantum Jumps Between Histories Concept

The phenomenon of dissipation is paradoxical from the point of view of standard physics. It is generally accepted that fundamental laws of physics are reversible but everyday reality is manifestly irreversible. Thus the situation is rather schizophrenic. Two worlds, the reversible and extremely beautiful world of fundamental physics and the irreversible and mathematically rather ugly "real" world, seem to exist simultaneously. The description of dissipation is highly phenomenological: one introduces mathematical monsters like non-Hermitian Hamiltonians; in particle physics particle decay widths are introduced by making energies complex; in macroscopic length scales one introduces parameters like friction coefficients, viscosity, diffusion constants, etc.. The mathematical beauty of the reversible world is lost and dissipation becomes an unavoidable nuisance of physics, which perhaps explains why so little conscious thought is devoted in the attempts to understand why these two worlds seem to co-exist.

This schizophrenic world picture is of course logically inconsistent. Something in the implicit assumptions underlying this paradoxical world view must be wrong. Quantum jump between quantum histories concept indeed resolves the paradox and explains the apparent existence of two worlds as resulting from a wrong view about psychological time. Without quantum jumps there would be single reversible reality behaving determistically and there would be neither dissipation nor consciousness. Quantum jumps between the reversible realities however cause dissipation, which can be more correctly seen as a self organization via quantum jumps and as a necessary prerequisite for evolution and consciousness. The source of all the ugly mathematics related to the description of dissipation is the failure to realize that there are two time developments: subjective time development proceeding via quantum jumps and geometric time development described by the dynamical equations without dissipation. The ugly dissipative terms in dynamical equations

result, when the sequence of quantum jumps between time developments is replaced with single dissipative time development. One can very loosely say that the dissipative world is envelope for the classical worlds, one classical world per CP_2 time. Or more concretely, dissipative space-time surface is the space-time surface going through a sequence of 3-surfaces defined by the values of psychological time measured using CP_2 time as unit.

Dissipation can be seen as a phenomenological description for the tendency of the self-organizing development by quantum jumps to lead to fixed points, limit cycles, limiting tori, strange attractors, etc.. in the space of quantum histories. In this description irreversible time development is "almost" envelope for the family of reversible time developments defined by quantum jumps: various parameters characterizing dissipation describe the deviation from the exact "envelopeness". Hence the study of chaotic dissipative systems could be also seen as a study of the phenomenological descriptions for the asymptotic behaviors yielded by the time development by quantum jumps. It is not of course clear whether this kind of effective description really works always or whether one should replace it by a genuine quantum description under some circumstances.

Consider as an example the description of a self organizing system using Haken's theory of self-organization relying on the hypothesis that system's states correspond to the minima of free energy function. Free energy depends on external parameters. When the value of some external parameter becomes critical, large fluctuations in long length scales occur and new level of self-organization with new length scale emerges or disappears in a phase transition like manner. For instance, potential well can split into two potential wells and system selects either well. This suggests that near the critical values of the external parameters quantum statistical determinism and hence also effective description fails at macroscopic length scales. The catastrophic changes in system's behavior could correspond to macroscopic quantum jumps. Biosystems obviously provide excellent candidates for critical systems. Since TGD Universe is quantum critical, any subsystem is basically critical system: only the time scale of the critical fluctuations determines whether given system looks critical from human point of view. In particular, selves are critical systems since the increase of the real entanglement above critical value means disappearance of self. Since time development corresponds to hopping in zero modes which are the fundamental order parameters in TGD framework, the picture of Haken applies almost as such as far as development in zero modes is considered. An interesting question is whether the criticality in zero modes actually corresponds to criticality for the disappearance or occurrence of new self.

Dissipation can be seen as an extremely concrete proof for the hypothesis that quantum jumps between quantum histories occur all the time. However, to possibly convince colleagues about this, very delicate experiments must be invented (say tribar effect testing the new concept of psychological time described in [K17] ! The crucial demonstration is however at the level of mere logic: 0 and 1 are the numbers needed, no experiments testing 10: th decimal for some quantitative prediction are needed.

Dissipation can be seen also as direct signature for consciousness and existence of selves Any system, which has ability to dissipate, to grow older, must have moments of consciousness in some length scales. Living systems are not the only systems growing old. Buildings and cars and computers grow old. Hydrodynamic flow without external energy fed gets older by gradually losing its velocity- (and Z^0 magnetic-) vortices. The rate of the energy loss by dissipation could be even seen as a rough measure for the level of consciousness.

The crucial question is however in which length scales quantum jumps occur: does all the dissipation occur in atomic length scales as standard physics strongly suggests or are all length scales involved as quantum criticality of TGD and new TGD based space-time concept suggest. Hydrodynamic flow is especially interesting example in this respect. The TGD based model for turbulent flow [K15]. with external energy feed assumes that dissipation occurs in all length scales: the decay of vortices of given radius to smaller vortices should therefore involve primitive consciousness in the length scale of the vortices. In turbulent flow with external energy feed there is stationary energy flow between space-time sheets of various sizes and this means that the level of consciousness, if indeed measured by energy dissipation, is same at various p-adic length scales involved. In this picture life as we know it, is a result of continual quantum self-organization of the sea water: indeed, we are 70 per cent of sea water.

One can represent an objection against above line of reasoning. The dissipative parameters of classical dynamics certainly make it ugly but this description is very practical. Should one really give it up at the fundamental level? This need not be the case. The above argument mentions

nothing about quantum classical correspondence, which in its strongest from requires that also quantum jumps sequences and therefore also dissipation should have space-time correlates. The failure of the classical determinism in the standard sense of the word for Kähler action caused by its immense vacuum degeneracy forces to replace space-like 3-surfaces with unions of space-like 3-surfaces with time-like separations so that there are good reasons to hope that these space-time correlates exist. In this framework zero energy ontology based on the notion of causal diamond is very natural. In zero energy ontology unitary S-matrix is replaced by a "complex square root" of the density matrix decomposing to a product of diagonal density matrix and unitary S-matrix and defining the time-like entanglement coefficients between the positive and negative energy parts of the zero energy state. Therefore thermodynamics becomes a part of quantum theory. Quantum classical correspondence in turn requires t that thermodynamical parameters have space-time correlates so that the ugly formulation of the dissipative dynamics at space-time level might allow a replacement by something more elegant. This seems to be possible.

The quantum numbers characterizing zero energy states couple directly to space-time geometry via the measurement interaction terms in Kähler action expressing the equality of classical conserved charges in Cartan algebra with their quantal counterparts for space-time surfaces in quantum superposition. This makes sense if classical charges parametrize zero modes. The localization in zero modes in state function reduction would be the WCW counterpart of state function collapse. Thermodynamics would naturally couple to the space-time geometry via the thermodynamical or quantum averages of the quantum numbers.

2.4 Co-Operativity, Long Range Correlations, Zero Modes And Quantum Entanglement

The generation of the long range order is one of the basic characteristics of the self-organized systems (the formation of Benard cells in Benard convection, the formation of Taylor's vortex belts in the rotation of a cylinder containing fluid, concentration patterns in Belounow-Zabotinsky reaction). In Benard convection the long range order corresponds to the formation of the Benard cells, whose size and shape depend on the temperature difference and the size and the shape of the vessel. In TGD Universe long range order can be generated in two manners.

The generation of long range order seems to be in contradiction with the fact that the increase of the energy feed should destroy macroscopic quantum bound states. For instance, in the case of Benard convection one could ask why one should not regard the stationary initial state as the state with maximal long range order. A possible way out of the dilemma is the fractal structure of the spin glass energy landscape. The external energy feed drives the system from the bottom of the energy valley which corresponds to a product of uncorrelated valleys, and it sooner or later ends down to the bottom of a deeper energy valley corresponding to a more stable state for which there are long range correlations between the degrees of freedom associated with the values of the initial valleys.

Entropic quantum entanglement between two selves destroys them as separate selves and creates higher level self, which behaves like single system. In the case of negentropic entanglements selves do not lose consciousness but its expansion. At the level of conscious experience this means a formation of a "whole" form its parts. An interesting question relates to the importance of quantum entanglement in self-organization and how closely it corresponds to the formation of long range correlations. "Ontogeny recapitulates phylogeny" metaphor suggests that quantum entanglement is geometrically realized as the formation of flux tube and this would suggest that generation of quantum entanglement requires a direct contact interaction in four-dimensional sense (particle exchange for Feynman graphs). In biosystems the quantum entanglement between cells could be generated during the replication of cell or via the mediation of magnetic flux tubes which are in key role in the model of DNA as topological quantum computer [K9]. For instance, in Benard convection heating could lead to decay of fluid particles and create quantum entanglement between the degrees of freedom associated with distant fluid particles. Also the formation of join along boundaries/flux tube condensates of large size (recall quantum criticality) could be involved in the formation of hydrodynamical quantum entanglement.

Zero modes are the fundamental order parameters in TGD framework.

1. Zero modes characterize the size, the shape, and the classical Kähler field of the space-time

surface, and are purely classical variables in the sense that a complete localization for them is in principle possible in each quantum jump.

2. It is not quite clear to me whether the non-existence of metric based volume element in zero modes forces the wave functions in zero modes to have a discrete locus. There certainly exists a symplectic measure defined by the symplectic form in zero modes. It does not however allow a complexification to Kähler form as it does in quantum fluctuating degrees of freedom. This symplectic from could define a hierarchy of integration measures coming as restrictions of $J \wedge J ... \wedge J$ with n factors to $2n$-dimensional sub-manifolds. Under some additional conditions- maybe the homological non-triviality of J and the orientability of the sub-manifold are enough, this measure would define a positive definite inner product and one would have a hierarchy finite-dimensional sub-spaces of zero modes. The maxima of Kähler function with respect to zero modes replace naturally the continuum with a discrete set of points and define the counterpart of the spin glass energy landscape consisting of the minima of free energy. Effective finite-dimensionality and even effective discreteness would be achieved.

3. Zero modes give rise to long range correlations in purely classical sense. This means that even macroscopic 3-surfaces can behave like elementary particles in zero modes: tornado is a good example of a locally chaotic particle like object.

Neural plasticity can be regarded as a self-organization. Sperry observed that when one splits the optical nerve of a frog, the nerve ends fuse again and frog begins to see [B1]. It seemed obvious that nerve ends recombine randomly and a genuine self-organization was in question. This hypothesis can be tested by rotating the eye of the frog by 180 degrees and looking what happens. If frog begins to see normally, genuine neural plasticity and self-organization is in question. If the field of vision is reverted then self-organization is not in question and nerve ends must somehow recognize each other, perhaps chemically. It was found that the frog begins to see things upside-down! A bad blow for self-organization paradigm at that time! Later it was however found that neural plasticity is a real self-organization phenomenon.

An interesting possibility (having at least entertainment value) to explain the disappointing result about frog's eye without losing the faith to self-organization in this particular case. Quantum entanglement might correlate the ends of the split nerve to form single coherent unit and to find each other after splitting. Biotelepathy would be in question. If this were the case, the paradoxical results of these experiments could be regarded as a direct support for biosystems as macroscopic quantum systems. In the same spirit one could also consider the possibility that the fundamental reason for why replication (and also pairing) occurs in biosystems is that replication and pairing creates quantum entangled systems just like the annihilation of photon creates quantum entangled pair of charged particles. In fact, it has turned out that the most elegant model for brain functioning results when one assumes that primary sensory qualia are experienced at a sub-cortical level, presumably at the level of the sensory organs. Quantum entanglement between brain and sensory organs and the TGD based view about long term memory allow to circumvent various objections against this view.

The model for DNA as topological quantum computer relies on the assumption DNA and lipids of nuclear and cell membranes are connected by magnetic flux tubes carrying dark matter. These magnetic flux tubes would appear quite generally and explain the miraculous looking phenomena like bio-catalysis, DNA replication, translation, and transcription based on the ability of biomolecules to find each other in a dense soup of bio-molecules. The basic mechanism would be the contraction *resp.* expansion of the flux tube induced by the reduction *resp.* increase of Planck constant. The phase transitions of gel phase would be based on this process and on the reconnection of magnetic flux tubes changing the topology of the web formed by the flux tubes.

2.5 Self Organization Requires External Energy Feed

Essential for the self-organization is external energy feed (Benard convection and even the general intuition about biosystems as systems living in the boundary between chaos and order). This can be understood on basis of Negentropy Maximization Principle [K18]. Only bound state entanglement is stable against the self measurement cascade giving rise to a state preparation during quantum

jump. When the system is subject to energy feed the bound states formed by the fused sub-selves decay and thus the number of selves increases and the system become more complex. Each self defines a self-organization pattern. At the level of very large energy feed system becomes chaotic.

The same principle applies in the case of brain and the level of metabolism determines whether brain is in a deep meditative state empty of mental images or in a chaotic state of high arousal. In [K28] a model of cognition based on the generation of hierarchical self cascades is proposed. Metabolism gives rise to the energy feed generating sub-selves. During meditation the energy feed is minimal and sub-selves bound state entangle to for very few sub-selves and a state of "one-ness" results. The fusion gives rise to a stereo consciousness (analogous to stereo vision resulting when left and right visual fields fuse).

In zero energy ontology zero energy state is quantum superposition over states with different energies of the positive energy state. Also super-position of states having different fermion numbers for positive energy state is possible as in case of coherent state of Cooper pairs. Thermal equilibria define square roots of special kind of zero energy states. In this framework the energy feed to the system means that the quantum superposition changes in such a manner that the average energy of the positive energy state increases. This excites new degrees of freedom and makes the system more complex. The dissipation caused by quantum jumps reducing entanglement entropy tends to reduce the average energy and this tendency is compensated by the energy feed selecting also the most stable self-organization pattern as a flow equilibrium.

2.6 Many-Sheeted Space-Time Concept And Self-Organization

TGD replaces ordinary space-time concept with a hierarchical structure of space-time sheets. For instance, in a proper TGD based description of Benard convection, there is hydrodynamics at each space-time sheet. The sheets of 3-space, which can be regarded basic units of flow (say vortices) at a given p-adic length scale appear as particles at larger space-time sheets. Space-time sheets form in a natural manner master-slave hierarchy: we must in general adopt our behavior to the slow dynamics of external world. This picture has counterpart at the level of CDs.

The original formulation of quantum TGD led to the conclusion that there are two kinds of space-time sheets: material space-time sheets and mind-like space-time sheets so that one can say that Matter Mind duality is realized in geometrical sense: of course, Mind is understood in the sense of cognitive representations only. What one means with mind like space sheets is however not at all obvious.

1. The original proposal was that mind like space-time sheets have a finite temporal extension. In zero energy ontology this holds true for all space-time sheets so that all space-time sheets are mind-like if this criterion makes sense. This could make perfect sense. For instance, the fermionic part of zero energy state can be regarded as a logical rule $A \to B$ with the instances of A and B represented as positive and negative energy fermion states in Fock basis: the Fock basis for many-fermion states indeed defines a representation of Boolean logic.

2. Mind like space-time sheets could be also interpreted as p-adic space-time sheets responsible for cognition whereas real space-time sheets would be matter like in the sense that they define the space-time correlates of sensory experience. The intersection of p-adic and real worlds is along rational and common algebraic points of the imbedding space and is discrete (note that this statement assumes the identification of preferred imbedding space coordinates). p-Adic space-time sheets could serve as natural correlates of cognition and intentionality and their interaction with real space-time sheets could give rise to effective p-adic topology crucial for the interpretation of p-adic mass calculations. p-Adic space-time sheets have infinite size in real topology so that cognition and intentionality could not be localized in brain. Only the cognitive representations defined by the intersections of real and p-adic space-time sheets allow this localization.

3. p-Adic space-time sheets can be mapped to real space-time sheets via a generalization of the canonical identification map which is continuous and maps rationals m/n, $m, n < p^k$, $k > 0$. to rationals. The explicit form of the map is $m/n \to I_k(m)/I_k(n)$, with $I_k(m)$ defined as

$$x = \sum x_n p^{nk} \to \sum x_n p^{-nk} \quad .$$

This map could define the effective p-adic topology for real space-time sheets in finite measurement resolution reducing to discretized real topology above distances defined by the p-adic length scale corresponding to p^k. Below the resolution length scale the impossibility to well-order p-adic numbers would correspond to the impossibility to order space-time points by physical measurements. What makes this map attractive is that it commutes with the discrete counterparts of various space-time symmetries in the resolution defined by p^k and is also continuous.

NMP tells that the subsystem with maximum quantum entanglement can perform quantum jump and in this quantum jump previous flow is replaced with a new one. In positive energy ontology one could argue that hydrodynamical equations alone can *never* give rise to the self-organized pattern of the Benard flow as asymptotic solution. In zero energy ontology relying on the failure of standard form of the classical determinism one can imagine the possibility that also the sequence of quantum jumps representing the self-organization process leading to the final pattern has space-time surface as a representative. The space-time sheets associated with the temporal sequences of sub-CDs could represent various steps in the self-organization process whereas the CD itself would represent the outcome of self-organization but in longer length and time scale (the sizes of CDs would come as powers of two). Larger CD could also code the asymptotic self-organization pattern in terms of external parameters such as energy feed dictating it and represented as long range classical fields.

TGD suggests a model of nerve pulse and EEG based on Josephson junction defined by cell membrane. More generally, the hierarchical structures formed by weakly coupled super conductors of various types seem to provide a very elegant general realization of conscious quantum control. Josephson junction networks are known to be self-organizing systems. The coherent light created by linear bio-structures, such as microtubules and possibly also DNA, is also a school example of self-organization [B3]. A gradual generation of phase coherence could in this case make possible the coherent oscillations of entanglement making possible self-organizing quantum jumps.

2.7 Infinite Primes And Self-Organization

p-Adic length scale hypothesis stating that the typical size of 3-surface is of order $L_p \simeq l\sqrt{p}$, l about CP_2 size, suggests that the p-adic prime associated with the 3-surface representing entire infinite universe is infinite. The construction of infinite primes [K14] suggests that the decomposition of infinite primes to finite primes corresponds to the decomposition of space-time surface or at least light-like 3-surfaces to regions obeying effective p-adic topology characterized by an finite prime.

This would mean that the effective p-adic topology in a particular sector of WCW corresponds to infinite prime P coding in very well defined sense the decomposition of $X^4(Y^3)$ to p-adic regions obeying finite-p p-adic topology and also providing the effective topology of $X^4(Y^3)$ in asymptotic regions of it: this would explain the success of physics based on real numbers.

The often stated intuitive belief is that real topology corresponds to the limit of p-adic topology as p approaches infinity. I must admit that I have not really understood this statement although it certainly makes sense if one considers solutions of polynomial equations with integer coefficients interpreted as equations in p-adic number field. In any case, this raises the question whether infinite primes could define p-adic topologies as such in the same manner as finite primes do. One can also consider the formulation of perturbation theory in powers of infinite prime p and thus containing only two non-vanishing orders. If one modifies the canonical identification to $I_k(m/n) = I_k(m)/I_k(n)$ defined previously, finite rationals are mapped to themselves already for $k = 1$ and infinite-p p-adic topology is more or less equivalent with the restriction of the real topology in the field of rationals.

Infinite-p p-adic space-time surfaces and real space-time surfaces would have rational points of imbedding space in common and the topology would be the same real topology in the set of rational points. This applies also at the level of WCW where point corresponds to 3-D light-like 3-surfaces. The number theoretic anatomy of the infinite prime would however code for the p-adic effective topologies of the light-like 3-surfaces characterizing the space-time surface via quantum holography: this decomposition corresponds to the structure of a particular point of the world of classical worlds.

There is entire hierarchy of infinite primes and infinite prime in general decomposes to infinite primes belonging to the lower level of infinity and at the bottom of this decompositional hierarchy are finite primes.

1. Infinite primes form a hierarchy such that infinite primes p_N at level N decompose in a well defined manner to infinite primes p_{N-1} at level $N-1$, which in turn.... decompose into infinite primes at the lowest level, which in turn decompose into finite primes.

2. The infinite primes of level $N-1$ label single boson and single fermion states of a supersymmetric theory. Therefore each infinite prime at level N corresponds formally to a many-particle state consisting of bosons and fermions. Those primes of level $N-1$ for which fermionic or bosonic occupation number are non-vanishing, define the entire system. "Ontology recapitulates phylogeny" metaphor suggests that the occupied infinite primes correspond to space-time regions appearing in the decomposition of the space-time surface to regions with different effective p-adic topologies. Thus the effective topology of D_P and the spectrum of p-adic topologies for the space-time surfaces in D_P correspond to each other in one-to-one manner.

3. The occupied fermion states of level $N-1$ are analogous to a subsystem of the many-particle state formed by fermions and bosons. By b), this subsystem corresponds to a union of p-adic regions of the entire space-time surface. A very tempting identification of this region is as the sub-universe to which NMP applies in the quantum jump. The sub-system of this sub-universe winning negentropy gain maximization race makes the quantum jump.

4. Actually space-time sheets identified in this manner form an entire hierarchy since similar decomposition occurs for each infinite prime at level $N-1$. The lowest level corresponds to infinite primes having decomposition to finite primes.

p-Adic evolution means that the infinite prime associated with the space-time surfaces appearing in final states of quantum jump increases in the long run. The increase of the p-adic primes associated with finite space-time regions in the long run and implies also the increase of infinite prime. This means that evolution at global level is implied by local evolution.

2.8 Illness As A Failure To Self-Organize Properly

One can consider two definitions of illness.

1. Structural illness: Illness as a loss of quantum coherence at some level. For instance, some group of neurons fails to form a quantum coherent system.

2. Functional illness: Illness as the failure to self organize effectively. For instance, cancer cells fail to organize to larger coherent units and behave in a selfish manner. Here Negentropy Maximization Principle relying on number theoretic variants of Shannon entropy suggests a manner to understand illness.

Actually, 1) might reduce to 2) since biosystems are not static systems but more like vortices in a stream with fluid particles being replaced with new ones all the time: self-organization creates various subsystems again and again. In zero energy ontology the equivalence of the two definitions would be even more natural.

It seems indeed possible to understand the illness qualitatively in TGD based theory of self-organization. In TGD framework one can envision living system as a dynamical hierarchy of selves. For instance, cognitive acts corresponds to self cascades, our thoughts correspond to sub-selves as also do various components of sensory experience. In this picture illness is pathology resulting from the inability of some sub-selves to remain conscious so that higher level self are not able to form mental images crucial for the survival. Some subsystems lose consciousness, and the system could be said to be ill.

The mathematical correlate for the loss of consciousness would be entropic entanglement with the external world. Subsystem can remain conscious by keeping the entanglement entropy below the maximum value defined by the measurement resolution or by generating negentropic entanglement. A superposition of states with both negentropic and entropic entanglement is generated in U-process and the subsequent process involves many selections.

1. One of them is state function reduction for M-matrix reducing as a special case to what is known as state preparation (reduction) for the positive (negative) energy part of the state. Since quantum numbers of the positive energy part of the zero energy state couple directly to the space-time geometry [K34], quantum numbers are mapped to classical variables (zero modes) in state function reduction in accordance with the basic hypothesis of the standard quantum measurement theory.

2. The selection of quantization axes is a further choice and means a localization to a particular sector of WCW for which the geometry of causal diamonds codes for the preferred measurement axis. A selection of single CD from quantum superposition of CDs would mean localization of the lower and upper times of CD. This does not seem to be consistent with the assumption that energy momentum eigenstates are in question and only approximate localization is expected to be possible. A further selection is selection of the page of the Big Book defined by the generalized imbedding space meaning also a selection of the value of Planck constant.

3. An example about a more abstract choice could be the selection between entropic and negentropic entanglement. If this choice, which essentially means selection of rationals from the continuum of reals or p-adics, is possible it could serve as the physical correlate for the choice between good and evil. One might argue that this selection is made possible at space-time level by the intersection of real and p-adic variants of the imbedding space. At WCW level it could correspond to a more abstract intersection with the counterpart of rationals identified as light-like 3-surfaces represented by rational functions with rational coefficients identifiable as common to real and p-adic worlds. State function reduction to the intersection of p-adic and real worlds would induce also the rationality of entanglement probabilities since they must make sense both p-adically and in real sense. One might say that the enlightenment means living in both real and p-adic world simultaneously.

4. These two interpretations for the intersection of real and p-adic worlds need not be independent. The absence of definite integral in p-adic number fields suggests that the transition amplitudes between p-adic and real sectors must be expressible using only the data associated with rational and common algebraic points (in the algebraic extension of p-adic numbers used) of imbedding space. This intersection is discrete and could even consist of a finite number of points. For instance, Fermat's last theorem tells that the surface $x^n+y^n = z^n$ contains only origin as rational point for $n = 3, 4, ...$ whereas for $n = 2$ it contains all rational multiples of integer valued points defining Pythagorean triangles: this is due to the homogenuity of the polynomial in question. Therefore p-adic-to real transition amplitudes would have a purely number theoretical interpretation. One could speak of number theoretical field theory as an analogy for topological field theory.

Why selves would then tend to chose the evil? Perhaps the reason is that this choice almost decouples the system from the external world and provides maximum freedom for action whereas strong negentropic entanglement reduces the number of degrees of freedom. The freedom is nice as long as the system is able to keep the entanglement entropy below the critical value and therefore avoids death as the prize of the sin. Note that even if the system identified at a given level of hierarchy behaves a saint, it probably happens that some of its subsystems are sinners. This conforms with the interpretation that meditative states involve minimum number of mental images so that there are not many sub-systems performing the wrong choices. One can of course claim that the sinners are needed since they lead to the re-organization and evolution of the system by destroying existing structures based on negentropic entanglement. Eternal life would be a catastrophe since it would not allow any evolution at all.

One could say that a healthy system consists of maximally alert subsystems able to stay wake-up by generating negentropic entanglement. This raises the question what "getting tired" means.

1. Getting tired could mean death of mental images: the entanglement of sub-selves with the external world becomes entropic and nearly critical leading eventually to the death of mental images and the system becomes drowsy. If also the system itself generates entropic entanglement it falls into sleep identified as a loss of consciousness. The interaction with the external

generates mental images and these sub-selves in turn tend to generate also entropic entanglement since only few of them are saints. This would mean that the dying of mental images is equivalent with getting tired.

2. In principle it would be possible to remain conscious by generating negentropic entanglement instead of sleep and perhaps meditative practices allow to achieve this. The question is why ordinary people are not able to achieve this by just getting tired. The first thing to notice is that meditators tend to get rid of their mental images. The sensory input and also thoughts are systematically eliminated. If entanglement entropy for the system is sum of the entanglement entropies of the various levels in the hierarchy assignable to the system (hierarchy of CDs and space-time sheets) then englightment is facilitated by enlightenment at lower levels and getting tired by entropic entanglement of mental images tends to lead to a loss of consciousness at the higher levels. Meditative practices indeed emphasize whole body consciousness achieved by exercises involving directed attention to all body parts. If all levels of the self hierarchy below given level contribute to the entanglement entropy then all length scales below the given length scale are relevant for the ability of the system generate negative entanglement entropy. Unless highly negentropic entanglement is possible in longer length scales (say at dark space-time sheets) the evolution of consciousness must proc

3. The proposed interpretation means that sleep identified as a loss of consciousness is in a well-defined sense regression. One can of course ask whether sleep really means a loss of consciousness: could it be that only memories are lacking from this period? Even if a loss of consciousness is in question as the arguments above suggest sleep could have many vital functions. For instance, the resting state would mean absence of sensory input at various levels and the absences of mental images would make easier for the subsystems to generate negentropic entanglement by meditating. Note that one can even consider the possibility that consciousness always means negentropic entanglement.

From the energetic point of view metabolism means the transfer of the metabolic energy from the nutrients to the system. This energy is ordered energy so that the energy feed can be seen as a feed of negentropy. One could perhaps say that biosystem "eats" negentropic entanglement or the ability to generate it.

1. The chopping of the nutrient molecules to their basic building bricks and the reconstruction of proteins and other bio-molecules from them would detach from the nutrient molecules the negentropic entanglement and leave only the waste having entropic entanglement with the external world. This raises some questions. How the interaction of the biomolecules of the body with the molecules of the nutrient leads to the transfer of the negentropic entanglement? Is the negentropic entanglement assignable to particular parts of the nutrient molecule transferred to the receiving system? How the fundamental ADP→ATP Karma's cycle relates to the transfer of entropic entanglement? Is phosporus ion perhaps a standardized negentropic entangler?

2. If magnetic flux tubes carrying dark matter serve as correlates for entanglement and also directed attention as assumed in the model of DNA as topological quantum computer [K9] then the transfer of negentropic entanglement would correspond to a re-connection of the magnetic flux tubes having direct information theoretic interpretation since the flux tubes serve as a correlate for the program of topological quantum computer. The end of a dark magnetic flux tube would be transferred from the nutrient molecule to a molecule of the living system providing it with negentropic entanglement. This would also provide a deeper level explanation for why the nutrients must be organic molecules.

From above one can conclude that illness as a failure to self-organize in normal manner is basically a failure to generate normal patterns of self-hierarchy. Some part of biosystem does not receive the needed entanglement negentropy feed. "Metabolism does not work properly" would be a more familiar manner to state the same thing. The mysterious ability (from classical physics point of view) of a self-organizing system to repair itself (get cured) can be understood as a consequence of the fact that system ends up with some self-organization pattern (fixed point of

iteration) automatically. The new element would the presence of choices between good and evil at every level of the hierarchy.

Some examples are useful in the attempt to concretize these ideas.

1. Healthy heart is sufficiently chaotic, not ordered. Quite generally, living systems seem to reside at the border between chaos and order. Suppose that "chaotic" really means chaotic rather than just complex. The border between chaos and order could be seen as a compromise in which the external energy feed creates a large enough number of patterns allowing to form representations about external world but does not yet lead to a total loss of negentropic entanglement at various levels of hierarchy. This borderline would naturally correspond to quantum criticality which can have several interpretations. One of them is as criticality with respect to the phase transitions changing the value of Planck constant.

2. According to TGD based model of nerve pulse and EEG [K25, K8], EEG is directly related to the oscillations of various Bose-Einstein condensates associated with neurons and possibly also glial cells. Large group of neurons could have simultaneously negentropic entanglement during coherent oscillations and synchronous firing could serve as a correlate for this collective behavior. Nerve pulse patterns could reflect a temporal loss of this coherence as individual neurons generate entropic entanglement and start to behave as individuals. The interpretation of spike patterns as communications indeed requires that neurons behave as separate selves. If the coherence of EEG is lost, neuron group ceases to behave like a coherent unit firing synchronically. The spatial coherence of EEG in brain could serve as a measure for the quantum coherence of brain. The spatial coherence EEG is indeed known to reflect psychic disorders. Similar loss of coherence could explain the behavior of cancer cell population and an interesting possibility is that some EEG type collective oscillation is missing from cancer cell population. If magnetic flux tubes serve as correlates of negentropic entanglement, de-coherence could reduce to a disorder of the magnetic body.

3. Both rising and lowering of the body temperature leads to the lowering and even loss of consciousness. The development of organisms able to control their body temperature and thus stay conscious in wide range of external temperatures is regarded as one the great evolutionary steps. A natural interpretation for the narrow range of physiological temperatures is in terms of quantum criticality vital for the possibility to self-organize to a large number of widely differing patterns making possible to react to the changing environment and form sensory and cognitive representations about it. For instance, the lipid layers of cell membranes are in liquid crystal phase only in narrow range of temperatures. Too low temperature means that the lipids are frozen. If the magnetic flux tubes connecting nucleotides of DNA to lipid layers define the braids involved with quantum computation, freezing makes quantum computations impossible [K9]. Too high temperatures in turn make the motion of lipids too chaotic. Also the quantum entanglement between the ends of flux tube can become entropic. Hallucinations associated with the fever could perhaps be regarded as a pathological state in which the feedback from brain generating virtual sensory input to sensory organs begins to dominate.

3 Haken's Theory Of Self Organization

Haken's classical theory of self-organization and the related model of pattern recognition (see the book "Information and Self-Organization" [B3]) is rather attractive in its simplicity and generality. Of course, the model cannot tell how the conscious experience associated with the pattern recognition is created but the concept of quantum jump might provide this lacking piece. The model generalizes also to a description of how biosystem acts on external world.

The potential wells representing attractors of the classical dynamics of the order parameter are replaced by the maxima of the Kähler function with respect to non-zero modes in quantum TGD based model. The zero modes of WCW geometry serve as control parameters and maximum depends on them. There are several maxima for given values of zero modes so that a typical catastrophe theoretic situation results and non-equilibrium phase transitions become possible.

3.1 Haken's Theory Of Non-Equilibrium Phase Transitions

The basic elements of Haken's theory [B3] are the concepts of order parameter and Slaving Hierarchy, Langevin and Focker Planck equations, maximum entropy principle and non-equilibrium phase transitions associated with the fluctuations of the order parameter at criticality.

3.1.1 Dynamical variables

Order parameters, denote them by q, are the fundamental dynamical variables in Haken's theory. They could be chemical concentrations, densities, some parameter specifying the geometrical conformation of system, etc. The basic element in Haken's theory is master-slave hierarchy. Slave possesses swift dynamics which follows the much slower dynamics of the master. Master typically appears as an external slowly varying parameter in the dynamics of the slave. In TGD larger space-time sheet, external world, typically serves as a master of the smaller space-time sheet, perceiver, in sensory perception. Situation could be also reversed: the reaction to the sensory experience is good example of this! p-Adic length scale hierarchy is a good example of master-slave hierarchy.

3.1.2 Dynamics

The dynamics of the order parameter is determined by a dissipative force proportional to the time derivative dq/dt of the order parameter, conservative force field defined as a gradient of a potential function $V(q)$ and random fluctuating force $F(t)$. In equilibrium the velocity is determined from the requirement that acceleration vanishes and this condition is known as Langevin equation. Potential function contains as external parameters the slowly varying order parameter of the master.

Fokker-Planck equation describes the devopment for the probability distribution $f(q,t)$ associated with the order parameter (an ensemble of identical systems is assumed: for instance, cells could form this kind of ensemble). Fokker-Planck equation is just the continuity equation for the probability density and the associated probability current containing convective term $\nabla_q V f$ proportional to the gradient of the potential $V(q)$ and a diffusive term proportional to the gradient $\nabla_q f(q,t)$ of the probability density.

3.1.3 Equilibria and maximum entropy principle

In non-equilibrium thermodynamics the requirement that entropy is maximal implies that in equilibrium situation the probability density $f(q)$ is proportional to the exponential of the potential function $V(q)$ and is hence analogous to Boltzmann weight:

$$f_{eq}(q) = N exp(-\frac{V(q)}{K}) \ .$$

K is analogous to temperature. V determines single particle correlation functions $\langle q_i \rangle$, two-particle correlation functions $\langle q_i q_j \rangle$ and also higher correlation functions for the components of the order parameter and this gives means of deducing the function V from experimental data. Typically a Gaussian modified with a fourth-order interaction terms is in question. There is a direct analogy with Higgs potential and non-equilibrium phase transitions have interpretation as symmetry breaking/restoration.

3.1.4 Non-equilibrium phase transitions

Non-equilibrium phase transitions are induced by a change in some parameter of the potential, typically the coefficient b of the quadratic term in

$$V = bq^2 - aq^4 \ ,$$

which represents master type order parameter itself. For instance, single potential well ($b < 0$) becomes unstable when b becomes positive ($b > 0$) and order parameter moves to either well of the double well potential. In a deformed potential Langevin equation leads rapidly to a new attractor corresponding to the free energy minimum of the potential: order parameter is captured by the nearest attractor. In Focker Planck equation spontaneous symmetry breaking with a selection of second potential well occurs.

3.2 Pattern Recognition In Haken's Theory

1. Perception gives rise to order parameter describing information about the external world. Visual field of the eye is a good example.

2. Each attractor of the order parameter dynamics corresponds to a characteristic pattern, feature. Grandma, apple, etc..

3. Pattern recognition is essentially feature detection and completion of the pattern to one of the characteristic patterns. Features are preferred patterns of q, which correspond to the minima of the free energy associated with the order parameter in question. Formally, features correspond to the eigenvectors of the quadratic part of the free energy determined by the inverse of the quadratic form defined by the correlation functions of the components of the order parameter.

4. Perception creates a pattern of the order parameter q. If the system is above criticality (there is minimum feed of metabolic energy to guarantee that one has $b > 0$ in the potential function) this leads to a rapid dynamics (Langevin equation) leading from the pattern near an attractor to the attractor, the feature. The dynamics clearly creates caricatures.

4 Non-Equilibrium Thermodynamics And Quantum TGD

Quantum TGD suggests the replacement of Haken's theory with a quantum description based on the generalization of the Thom's catastrophe theory to WCW context ("world of classical worlds", briefly WCW) and the introduction of spin glass analogy and p-adic fractality at the fundamental level.

1. If the space of 3-surfaces with fixed values of zero modes is infinite-dimensional symmetric space [K6], one can expect that there is a single maximum of Kähler function in quantum fluctuating degrees of freedom and that one can effectively consider only the maximum just as in the case of integrable quantum systems.

2. Zero modes correspond to non-quantum fluctuating degrees of freedom and define a natural quantum counterpart of control variables. As already explained, under rather general assumptions it is possible to have have a hierarchy of wave functions with 2n-dimensional locus in zero modes and reducing effectively to the exponent of Kähler function. Therefore the maxima of Kähler function with respect to zero modes define an effective discretization of zero modes and give rise to the counterpart of spin glass energy landscape.

3. The discretization of the partonic 2-surfaces X^2 by replacing them with the discrete set of the loci of fermions at X^2 is the counterpart for the finite measurement resolution. This means the replacement of light-like 3-surfaces with braids and a connection with topological quantum field theories. At space-time level one has 2-dimensional string world sheets connecting the braid strands belonging to separate light-like 3-surfaces and a connection with string model based description emerges. If stringy effects can be neglected, discretization effectively replaces WCW with a finite cartesian power of imbedding space. Note that the induced Kähler form of CP_2 associated with space-time sheet defines important class of zero modes and this information is lost in this approximation. In any case, in these approximations TGD based theory would be finite-dimensional and would in many respects resemble Haken's theory.

There are also several profound differences.

1. p-Adic length scale hypothesis is an essential part of TGD based approach and makes possible quantitative predictions based on simple scaling arguments. A more speculative hypothesis is that infinite primes characterize the p-adic length scale assignable to a light-like 3-surface so that a given sector of WCW would be characterized by infinite prime. The latter assumption does not have practical implications.

2. The hierarchy of Planck constant implying the generalization of the notion of imbedding space plays a key role in biological applications. Magnetic flux tubes would serve as correlates for entanglement and directed attention. The contraction and lengthening of magnetic tubes induced by the phase transitions changing Planck constant and their reconnection could define the basic mechanisms of bio-catalysis. Magnetic flux tubes would also serve as braids and make possible topological quantum computations.

3. Quantum criticality means that space-time surfaces are critical in the sense that there is an infinite number of deformations of the space-time surface with a vanishing second variation of Kähler action [K34]. In the framework of catastrophe theory this means that the system resides at the critical manifold for which several (now infinite number of) branches defined by the extrema of potential function co-incide so that the rank of the matrix defined by the second derivatives of the potential function is reduced and even some higher derivatives can vanish (as in the tip of the cusp catastrophe). These critical manifolds define an inclusion hierarchy just as in Thom's theory and to this hierarchy one can speculatively assign inclusion hierarchy of super-conformal algebras and of hyper-finite factors of type II_1, which play a key role in the formulation of quantum TGD.

   The natural expectation is that the number of critical deformations is infinite and corresponds to conformal symmetries naturally assignable to criticality. The number n of conformal equivalence classes of the deformations can be finite and n would naturally relate to the hierarchy of Planck constants $h_{eff} = n \times h$ (see **Fig. ??** in the appendix of this book).

4. One cannot avoid bringing in also quantum theory of consciousness. Zero energy ontology replaces classical state with zero energy state analogous to a physical event or process, and S-matrix is replaced with the pair defined by U-matrix and M-matrix. U-matrix characterizes quantum jumps between zero energy states and makes possible volitional action. M-matrix characterizes zero energy states and is assigned with perception. Quantum jump corresponds to perception-reaction pair and defines the counterpart for the basic iterative step of self organization (note that state function reduction and state preparation combine to a single state function reduction in zero energy ontology). NMP defines the variational principle of consciousness theory. The notion of number theoretical Shannon entropy brings in the choice between quantum jumps generating positive *resp.* negative entanglement entropy. This choice between co-operation and maximal independence could be a correlate for a conscious choice between good and evil. This aspect should allow a statistical description in terms of a probability of being sinner or saint.

4.1 Spin Glass Analogy

At the level of WCW geometry spin glass analogy is well understood. The WCW CH consisting of 3-surfaces in H has fiber space structure. Fiber corresponds to nonzero modes of WCW metric contributing to the line element of metric and base corresponds to zero modes in which line element vanishes (see **Figs. 1**, **2**). Spin-glass analogy implies large degeneracy of the absolute minima of Kähler action. In the approximation that classical gravitation can be neglected all extremals of Kähler action are degenerate and CP_2 canonical transformations are $U(1)$ gauge symmetries in fiber degrees of freedom: actually however $U(1)$ gauge symmetry is broken and the gauge-related space-time surfaces are not gauge-equivalent configurations so that spin-glass analogy results. The functional integration around maxima of Kähler function as function of fiber coordinates gives well define results since Gaussian determinant and metric determinant cancel each other.

The localization in zero modes around single maximum of Kähler function in quantum jump could mean that they are equivalent with measurement resolution. Symmetric space property in turn suggest that the integration over fiber degrees of freedom reduces to an integral around single maximum of Kähler function. This would mean huge simplification in the construction of the theory since very close resemblance with the formalism of quantum field theory would results as a consequence. The physical picture of quantum field theories certainly suggests this strongly.

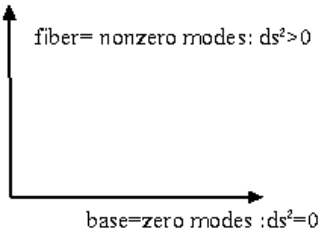

Figure 1: WCW has fiber space structure. Fiber corresponds to coordinates appearing in the line element and base to zero modes, which do not appear in the line element.

4.2 Maxima Of The Kähler Function As Reduced Configuration Space Ch_{red}

When one calculates the probability amplitude for a given quantum jump, given as the inner product between WCW spinor fields, one obtains an integral of the fermionic Fock space inner product as a functional of 3-surface X^3 over fiber degrees of freedom around maxima of Kähler function as function of fiber coordinates: if the most optimistic expectations are realized, only single maximum contributes. This integral can be calculated approximately by performing Gaussian perturbation theory. Thus the *maxima* of the Kähler function, which are completely analogous to the free energy minima of spin glass, can be identified as the reduced WCW CH_{red}. The ill defined Gaussian and metric determinants cancel each other and the non-locality of Kähler function as a functional of 3-surfaces implies that the standard divergences of the local quantum field theory are absent.

The number of maxima for given values of zero modes can be large: This is in fact expected since only classical gravitational action differentiates between symplectic transforms of a given preferred extremal. In particular, the presence of mind-like space-time sheets is expected to give rise to huge degeneracy. Thus CH_{red} has many-sheeted structure which each sheet parameterized by zero modes and a generalization of catastrophe theory to infinite-dimensional context is needed to describe the situation mathematically. This degeneracy corresponds in the simplest case to the degeneracy of state associated with cusp catastrophe (see **Fig. ??**) and phase transition like quantum jumps corresponds to selection of one of the various allowed branches.

The simplest manner to understand the expected decomposition of the reduced WCW to different regions D_P characterized by a collection of p-adic primes is to assume that $exp[K_{max}]$ is p-adic fractal as a function of the zero modes. p-Adic fractality is suggested both by criticality and by spin glass analogy. p-Adic fractality implies automatically ultra-metric hierarchy at the level of WCW allowing the decomposition of CH_{red} to a tree like structure. This kind of hierarchy is suggested by Parisi [B2] to be fundamental for the biological information processing, especially for the formation of concepts and classification into categories.

4.3 The Concepts Of Quantum Average Effective Space-TimeAnd Many-Sheeted Space-Time

If the most optimistic expectations hold true, functional integration in fiber degrees of freedom reduces to integration around some maximum X^3_{max} of Kähler function with respect to fiber coordinates. It is convenient to identify the space-time surface $X^4(X^3_{max})$ as "quantum average effective space-time". Since WCW integration occurs over the sector D_p associated with the final

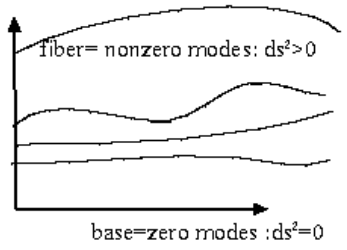

Figure 2: The reduced WCW CH_{red} has many-sheeted structure with each sheet parameterized by zero modes.

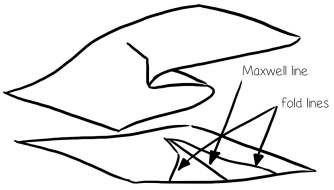

Figure 3: Cusp catastrophe. In this case CH_{red} has two sheets (intermediate sheet is not maximum of Kähler function).

state of the quantum jump, effective quantum average space-time characterizes final state and can be regarded as a representative example from the set of space-time surfaces appearing in the final state, which all have same macroscopic characteristics.

One can associate this space-time surface only with the final state of the quantum jump and the sequence of quantum jumps defines a sequence of space-time surfaces of this type. As already explained, dissipative time evolution could be interpreted as kind of envelope for this sequence of reversible time evolutions. TGD however allows to code for thermal parameters to space-time geometry via the coupling of the Kähler-Dirac action to average values of the quantum numbers for the positive energy part of the state. Classical Langevin dynamics for order parameters can be identified as the counterpart of the hopping in zero modes and in degrees of freedom characterizing various degenerate absolute minima associated with the maxima X^3_{max} of Kähler function.

A new element related to quantum average space-time relates to how GRT emerges as a limit of TGD. GRT space-time as effective space-time is obtained by replacing many-sheeted space-time with Minkowski space with effective metric determined as a sum of Minkowski metric and sum over the deviations of the induced metrices of space-time sheets from Minkowski metric. Poincare invariance suggests strongly classical Equivalence Principle for the GRT limit in long length scales at least. One can consider also other kinds of limits such as the analog of GRT limit for Euclidian space-time regions assignable to elementary particles. In this case deformations of CP_2 metric define a natural starting point and CP_2 indeed defines a gravitational instanton with very large cosmological constant in Einstein-Maxwell theory. Also gauge potentials of standard model correspond classically to superpositions of induced gauge potentials over space-time sheets.

Gravitational constant, cosmological constant, and various gauge couplings emerge as predic-

tions. Planck length should be related to CP_2 size by a dimensionless numerical factor predicted by the theory. These constants need not be universal constants: cosmological constant is certainly very large for the Euclidian variant of GRT space-time. These constants could also depend on p-adic length scale. p-Adic coupling constant evolution suggests itself as a discretized variant of coupling constant evolution and p-adic scales would relate naturally to the size scales of causal diamonds: perhaps the integer n characterizing the multiple of CP_2 scale giving the distance between the tips of CD has p-adic prime p or its power as a divisor.

At microscopic level one has many-sheetedness. Sheets themselves are extremely simple objects as preferred extremals of Kähler action analogous to Bohr orbits and provide the analogs of atoms for GRT space-time which is much more complex. Zero Energy Ontology means that the 3-surfaces defining the ends of space-time surface at the light-like boundaries of causal diamond would fix the space-time surface highly uniquely. The preferred extremal property gives a non-trivial correlation between the ends analogous to that for the ends of Bohr orbit.

Zero energy ontology implies also that the maxima of Kähler function correspond to preferred time evolutions since the maximum property fixes both ends of the space-time surface. Entire temporal self-organization pattern become basic objects. In the applications to biosystems this is of utmost importances and gives hopes of understanding processes like morphogenesis which look mysterious in positive energy ontology.

The notion of magnetic body is central in TGD inspired quantum biology [K35]. Magnetic body contains dark matter identified as a phases of ordinary matter with large effective value of Planck constant $h_{eff} = n \times h$. Magnetic body controls biological body, receives sensory input from it, and parts of it serve also as templates for its formation. Phase transitions changing the value of h_{eff} and thus flux tube lengths provide basic mechanisms of bio-catalysis. Cyclotron radiation with large value of h_{eff} can have energy above thermal energy and allows the control of biochemical reactions if the dark photon energies are in the visible and UV range assignable to biophotons.

What is important that magnetic body is 4-dimensional so that its time evolution can code for morphogenesis. Replication would basically reduce to that for 3-D magnetic body and would correspond to a fundamental vertex analogous to 3-particle vertex for Feynman diagrams. Already in 3-D context the braiding of the magnetic body brings in possibility of topological quantum computation using braiding of the flux tubes. In 4-D context braiding is replaced by 2-braiding occurring for string world sheets defined by the flux tubes idealized to string. String world sheets emerge also as real objects the modes of Kähler-Dirac equation are localized at 2-D surface from the condition that electromagnetic charge is well defined. 2-braiding brings in besides ordinary braiding also reconnection of flux tubes and one ends up to a speculation that DNA sequences actually code for the 2-braiding of the magnetic body.

4.4 Haken, Thom, Penrose And Hameroff

The picture leads to a generalization of Haken's theory of non-equilibrium phase transitions to a Penrose-Hameroff type picture [J1]. Any quantum jump corresponds to a selection of space-time surfaces as the relevant maximum of Kähler function and the fundamental order parameters are the zero modes characterzing the space of these 3-surfaces. Non-equilibrium phase transitions correspond to quantum jumps leading to a selection of one maximum, from a quantum superposition of several ones appearing in the state $U\Psi_i$. The classical theories of Haken and Thom correspond to the hopping motion in zero modes. The sequence of quantum jumps leads to the regions of WCW at which vacuum functional is maximum and when Kähler function has several maxima this leads with great probability to hopping from one sheet of the catastrophe surface to another. For volitional quantum jumps selecting between maxima of Kähler function in fiber degrees of freedom, one ends up with the quantum versions of these theories in which genuine phase-transition like quantum jump selecting between the sheets of the catastrophe surfaces occurs near the "Maxwell line": the Penrose-Hameroff proposal [J1] for the orchestrated reduction of state function is analogous to this kind of selections.

4.5 Classical Gravitation And Quantum Self-Organization

The symplectic transformations of CP_2 acting as local $U(1)$ gauge transformations leave zero modes invariant since they do not affect the induced Kähler form of CP_2. The classical gravitational interaction breaks local $U(1)$ invariance as a gauge symmetry of the Kähler action and means that the action of a symplectic transformation spoils the preferred extremum property in general: gauge degeneracy transforms to spin glass degeneracy in 4-D sense. This means that symplectic transformation become dynamical symmetries acting as symplectic transformations only at the partonic 2-surfaces defined by the intersections of wormhole throats with the boundaries of causal diamonds. In the interior of space-time sheet their action is not symplectic anymore and Kähler action is affected: this is necessary for having a non-trivial Kähler metric in WCW . The symmetric space property for the preferred extremals suggests that there is single maximum of Kähler function at the orbit of the symplectic group defined by the symplectic deformations of the partonic 2-surface.

The value of the Kähler action depends only very weakly on the symplectic degrees of freedom. Hence one expects a large number of space-time sheets with almost identical value of Kähler function. Only the contribution of the induced metric proportional to R^2 (R denotes CP_2 radius) distinguishes between almost degenerate extremals in the lowest approximation. Since space-time surfaces code for the four-momenta of partons [K34], one expects that the contribution is expressible in terms of quantities GM_i/L, where M_i are mass parameters and L a length scale naturally defined by the size of CD. This kind of expression indeed follows from general arguments for the form of the measurement interaction term. For $L >> 2GM$, (Schwartschild radius) one has $GM/L << 1$. This situation corresponds to a non-perturbative situation in the sense that a very large number of preferred extremals gives a sizeable contribution to the vacuum functional.

Non-perturbative phase seems to emerge also in different manner above Planck mass scale. The coupling constant parameter $GM_1M_2/\hbar$ is analogous to gauge coupling strength $\alpha = g^2/4\pi\hbar$ appearing in perturbation theory. It becomes large above Planck length scale and one can argue that perturbation theory fails. On basis of the experience with hydrogen atom one can also argue that also the non-perturbative quantum description of gravitationally bound states in terms of Schrödinger equation fails. The proposal is that the hierarchy of Planck constants saves the situation [K29, K21]: a phase transition increasing $\hbar$ and guaranteeing the smallness of $GM_1M_2/\hbar$ takes place. Equivalence Principle fixes the form of $\hbar_{gr}$ to $\hbar_{gr} = GM_1M_2/v_0$, where $v_0 < 1$ corresponds physically to a velocity. Planck length redefined as $\sqrt{G\hbar_{gr}}$ is transformed to $GM/\sqrt{v_0}$ and is of the order of Schwartshild radius. Above this length scale non-perturbative phase prevails if the previous argument is accepted. The implication would be macroscopic quantum coherence at astrophysical scales with a gigantic value of Planck constant at the space-time sheets mediating gravitational interaction [K29, K21].

For condensed matter densities Planck mass corresponds to the length scale of 100 μm defining the size scale of a large neuron. These observations suggest that macroscopic quantum phases at the space-time sheets mediating gravitational interaction are fundamental in TGD and also in TGD inspired quantum biology. The almost degenerate preferred extremals could define the TGD counterpart for the gravitationally degenerate microtubule conformations of Penrose and Hameroff [J1]. In Penrose-Hameroff theory gravitons are believed to play important role. The vacuum Einstein tensor associated with the preferred extremals (say massless extremals) is indeed expected to generate a coherent state of gravitons characterized by large value of Planck constant so that $E = hf$ relationship implies that very low frequency gravitons are energetic. An interesting possibility is that these coherent states of gravitons give rise to the sense of proprioception.

4.6 Quantum Model For Perception And Reaction

All quantum jumps involve both active and passive aspects of consciousness and it is interesting to look for a general model for active and passive aspects of consciousness based on the generalization of Haken's theory. Before continuing, one must notice that the meaning of the active-passive dichotomy depends on one's tastes. One could argue that the genuinely active aspect corresponds to the U process generating the quantum superposition of possibilities and that the subsequent selections correspond to the passive aspect. Also volition as a selection between given options would be a passive aspect. Second interpretation is that only that part of the selection process

which has a clear identification in terms of volitional acts corresponds to the active aspect whereas perception would correspond to the passive aspect. It is however known that sensory perception is to some extent a process involving also a selection between alternative sensory percepts (binocular rivalry).

Consider first the general picture.

1. In TGD the fundamental order parameters correspond to the zero modes of WCW . Kähler-Dirac action containing a measurement interaction term couples various conserved quantum numbers to the dynamics of the space-time surface so that standard quantum measurement theory results. Since partonic 2-surfaces carry the quantum numbers the coupling is to the zero modes characterizing the induced Kähler in the interior of the space-time surface.

2. In positive energy ontology volitional acts would select between initial values defining initial value sensitive dynamical developments of the 3-surface. In zero energy ontology the selection is between entire time developments, which are not deterministic in the standard sense of the world. This means a hierarchy selections at various time scales associated with the hierarchy of CDs. Quantum criticality is a more natural notion than initial value sensitivity in this framework. The fractal hierarchy of criticalities means that critical manifolds contain catastrophe surfaces which in turn have critical surfaces.

3. The outcome of the selection process is 4-D dynamical pattern rather than time=constant snapshot. This interpretation is especially natural in living matter where spatio-temporal EEG patterns characterize the state of brain.

4. Besides state function reduction in geometric degrees of freedom there are selections in spin degrees of freedom of WCW spinor field. Zero energy WCW spinor fields allow interpretation as superpositions of Boolean statements and the natural interpretation would be that state function reduction in these degrees of freedom gives rise to Boolean cognition and WCW spinor fields represents rules of type $A \to B$ as superposition of all instances. Boolean cognition would be analogous to sensory perception.

In TGD framework the dynamics for order parameters corresponds basically to hopping in the space of order parameters. Therefore the statistical description of hopping as a continuous motion is expected to be an excellent approximation. The motion is much like Brownian motion in presence of drift term. Langevin dynamics for order parameters can be regarded as a model for the hopping in the space of order parameters. Focker-Planck dynamics applies, when the number of nearly identical space-time sheets each characterized by zero modes is large so that one can apply quantum statistical determinism. One can also introduce probability distribution also for single space time sheet to describe the distribution of zero modes defined by quantum jumps during some macroscopic time scale.

The hopping in the space of order parameters must lead to the region of order parameter space in which the modulus squared of the configuration space spinor field has maximum. The simplest situation is that the maxima correspond to the maxima of vacuum functional as function of order parameters. Since vacuum functional is exponential of Kähler function, this means that Kähler action for space-time sheet representing subsystem containing zero modes as external parameters takes the role of the potential function in Haken's theory.

If sensory experience is determined by the localization in zero modes then feature detection must correspond to Langevin type dynamics leading to some minimum of potential function and in TGD it corresponds to a hopping motion leading to attractors defined by several maxima of the Kähler function as a function of zero modes. For instance, in the case of cusp catastrophe quantum jumps lead rapidly from the stable sheet of catastrophe to another in the vicinity of Maxwell line. Conscious feature detection would require that there is sub-self defining mental image whose sensory experience is dictated by the localization in zero modes characterizing feature. It seems that this requires macroscopic quantum phases whose order parameters in ground state are determined by the values of zero modes. The essentially quantal element of the feature detection is the wake-up of the sub-self whose subsequent self-organization gives rise to a mental image depending only weakly on initial conditions. A general model for this wake-up mechanism is based on the quantum jumps induced by Josephson currents running between two superconductors representing master

and slave. These quantum jumps are induced resonantly in slaved superconductor, when the frequency of the Josephson current corresponds to the energy difference for the states of the slaved superconductor [K22, K23].

The recognition of phonemes takes place in definite places in the linguistic regions of brain. This suggests that the same input comes into each of these detectors and gives rise to yes-no response so that cusp catastrophe would be in question. The assumption that various phoneme detectors receive same input data is in accordance with the ideas about hologram like data representation in brain. Generalizing, it seems that some parts brain could be to some extent act as a collection of simple yes-no feature detectors receiving essentially the same input.

4.7 Are Proteins Quantum Spin Glass Type Systems?

The entire universe should be quantum spin glass type system if TGD is correct. There is indeed some evidence for the spin glass nature of biosystems at protein level [I3, I3]. A long standing problem of molecular biology is to understand why proteins [I7] fold to very few preferred spatial conformations only [I6, I2]. I have discussed a TGD inspired model for protein folding [K1], which is completely unrelated to the following discussion.

A naive expectation, assuming *random* amino-acid sequences, is that folding should occur randomly. It would however would however require the age of the Universe for the protein to fold in this manner [I2]. According to the article [I3, I3], Ken Dill has simulated proteins using a simplified computer model in which the 20 amino-acids are replaced with 2 model amino-acids: "hydrophobic" or "hydrophilic". It has turned out that only few per cent of these virtual proteins are good folders. The lesson seems to be that random sequences of amino-acids are not sufficiently protein like and that good folders have some specific property allowing them to arrive at a unique shape.

4.7.1 Could protein spin glass energy landscape have single deep valley

According to the same article, Peter Wolynes suggests that proteins are spin glass type systems characterized by a fractal like energy landscape containing very many nearly degenerate energy minima. This means that system has difficult time in finding low energy arrangements and it can end up to any one of the very many energy minima with almost degenerate energies. Therefore *typical* spin glass like system is not a good folder. Wolynes suggest that, as a consequence of natural selection, real proteins differ from random proteins in that they have one deep energy minimum besides shallow minima still present. The energy landscape is still rugged but now there is one preferred configuration at the bottom of a deep energy valley. Also the states near this state are assumed to have energy below the average energy. This funnel like structure in energy landscape is proposed to be a solution to the folding paradox. One can understand the correct folding to result from external perturbations: if protein is put in hot liquid, thermal perturbations take care that it is not left in any local energy valley during cooling but ends up to the deep energy minimum. Minimization of free energy could also selet good folders during evolution starting from a soup of random amino-acid sequences.

If protein is in self state, quantum jumps inside it occur and imply quantum self-organization leading toa preferred final state pattern selected by dissipation. This pattern represents protein folding depending on the external parameters like pH, ionic concentrations and temperatures whereas the dependence on the initial state is very weak. Thus the phenomenon of protein folding gives direct support for the self-hierarchy and consciousness in even protein length scales.

One can also try to estimate the time scales involved. According to [I7] the time times for protein folding vary in the range $10^{-1}-10^3$ seconds both in vivo and vitro. According to Wikipedia article [I2] the times for small proteins with lengths up to hundred residues fold in single step and the time scale is 1 millisecond and the shortest time scales are in microsecond range. The question is whether these time scales could be understood without making any dynamical assumptions by using only p-adic length scale hypothesis.

1. The naive application of p-adic length scale hypothesis before zero energy ontology would suggest that the duration of the protein self is of order $T_p = L_p/c = L(k)/c$ for $p \simeq 2^k$. For the p-adic length scale $L(151) \simeq 10^{-8}$ meters (cell membrane thickness) this gives $T_p \sim 10^{-15}$ seconds. This time scale is quite too short.

2. One might argue that in zero energy ontology the secondary p-adic time scale $T_{2,p} = \sqrt{p}L_p$ of the CD, where the p-adic length scale L_p characterizes the protein or the folding mechanism is relevant. One can consider several identifications of L_p. What comes first in mind are the length of the protein, the size scale of the folded protein, and the thickness of the amino-acid sequence. Also the p-adic length scale of electron or proton inducing catalytically crucial steps in the folding of short proteins could determine $T_{2,p}$. For $k = 151$ (cell membrane thickness) this would give a time scale of order 10^5 seconds, roughly 50 hours. $k = 145$, which corresponds to nanometer length scale and thickness of the protein, would give a time scale of one hour, which corresponds to the experimental upper bound according to [I7].

   $k = 127$ corresponding to electron would give a secondary time scale of .1 seconds, which is the lower bound according to [I7]. The interpretation could be that single electron initiates the folding process catalytically. Millisecond would correspond to $L(k = 120) \sim 10^{-13}$ m. This could correspond to the p-adic scale for quarks with mass about 5 MeV. Quarks and antiquarks indeed appear at the ends of (wormhole) magnetic flux tubes in the model of DNA as topological quantum computer. If the interpretation is correct the two fundamental time scales of living matter would correspond to elementary particles. The fastest time sale of order microsecond could correspond to the p-adic length scale of proton giving a time scale of order 10^{-7} s: this could make sense if proton is essential for the catalytic step involved. I have indeed proposed that the dropping of electrons and protons between space-time sheets defines key element of bio-catalysis [K1].

   In many-sheeted space-time particles topologically condense at all space-time sheets having projection to given region of space-time so that this option makes sense only near the boundaries of space-time sheet of a given system. Also p-adic phase transition increasing the size of the space-time sheet could take place and the liberated energy would correspond to the reduction of zero point kinetic energy. Particles could be transferred from a portion of magnetic flux tube portion to another one with different value of magnetic field and possibly also of Planck constant h_{eff} so that cyclotron energy would be liberated.

   In the following only the "dropping" option is discussed.

3. The appearance of.1 second time scale characterizing electron and defining a fundamental bio-rhythm is intriguing as is also the appearance of the millisecond time scale defining the time scale of nerve pulses. The hierarchy of Planck constants brings in additional scaling of the time scale by the ratio $r = \hbar/\hbar_0$. If dark protons are involved one could understand all three time scale ranges if r is in the range $10^3 - 10^4$. The TGD based model of EEG [K8] assumes that the preferred values of Planck constant come in powers of 2^{11}, which happens to be near to the proton-electron mass ratio. If the secondary p-adic time scales correspond to those of electron, quarks, and proton inducing basic catalytic steps of the folding then the variation of r in the range $1 - 10^4$ would predict time scale ranges $10^{-7} - 10^{-3}$ s for proton induced folding, $10^{-3} - 10$ s and $.1 - 10^3$ s for electron induced folding.

These very naive arguments suggest that the general order of magnitude for the folding time might have something to do with the p-adic length scale hypothesis in zero energy ontology.

4.7.2 Should one replace thermal spin glass with 4-D quantum spin glass?

Wolynes models protein as a thermal spin glass. TGD suggests that the entire universe is quantum spin glass. The partition function of spin glass (or rather the average over the partition functions with different coupling strengths between spins) is replaced with vacuum functional, which is exponent of Kähler function. The averaging over the coupling constant strengths corresponds in TGD to the average over so called "zero modes" of the Kähler function: using QFT terms, these degrees of freedom do not couple to the inverse of the propagator defined by the Kähler function. Zero modes characterize the shape and size of the 3-surface and also the classical induced Kähler field on it (classical em field is very closely related to Kähler field) and can be identified as fundamental order parameters in TGD inspired quantum theory of self-organization. In each quantum jump localization in zero modes occurs so that averaging is indeed genuine statistical averaging: quantum states representing the final states of quantum jumps are not de-localized in zero modes.

Evolution at quantum level has selected those proteins for which the rugged "energy landscape" defined by the negative of Kähler function contains only few deep minima. One can criticize the assumption about the selection of the spin glass energy landscape as too strong. There are always deep minima and depending on the initial conditions self-organization leads to some minimum. On the other hand, selection certainly occurs also in the sense that proteins and corresponding spin glass energy landscapes are selected by evolution.

The proposed mechanism might be a general mechanism of evolution. In the generalization of Haken's self-organization theory to quantum TGD context the maxima of the Kähler function correspond to those configurations to which self-organizing system rapidly moves if perturbed. For instance, pattern perception could be described as a dynamical evolution leading to one of few maxima identifiable as "features", which are caricature like patterns providing idealization of the actual sensory stimulus. "Features" would correspond to configurations with one deep minimum of the negative of the Kähler function selected during evolution. Also preferred behavioral modes developed during evolution, "phylogenetic invariants", could have similar identification.

As a matter fact, quantum self-organization should occur even in elementary particle length scales. The duration of elementary particle selves can be estimated from the p-adic length scale hypothesis to be of the order of Compton time determined by the particle mass. Self-organization could explain the selection of preferred p-adic primes characterizing elementary particles and also macroscopic space-time sheets.

4.7.3 Could zero energy ontology and conscious choice be significant factors in the protein folding?

The proposed view about selection of protein conformations is quantal and involves the notion of 4-D spin glass but does not involve zero energy ontology and hierarchy of Planck constants. It was already noticed that the introduction of hierarchy of Planck constants might allow to understand the rough time scales of folding in terms of the secondary p-adic time scales assignable to electron and proton without detailed assumptions about dynamics.

1. In zero energy ontology state function reduction selects one particular folding process rather than a particular folding. The folding process is a sequence of quantum jumps selecting a folding process and then acting on it by U-matrix. The entire folding process including the initial folding is affected in the folding process. The final state is asymptotic self-organization pattern. The asymptotic classical folding process should always lead to the same preferred folding and also begin from the same folding.

2. Fractals are indeed typically fixed sets of iteration and quantum jump sequence is analogous to iteration so that this principle might apply quite generally. By quantum classical correspondence the classical folding should reflect this fractality. The folding process is predicted to have a modular structure with a hierarchy of length and time scales defined by CDs involved. The choice of the folding process would proceed simultaneously in all scales and presumably the fixed point would be reached first in shorter scales so that the folding process would proceed from short to long scales.

3. If the asymptotic classical folding is invariant under the classical folding dynamics, the sequence of quantum jumps leads naturally to a fixed point of the classical folding dynamics in various scales defined by the hierarchy of CDs. Therefore the change of the geometric past and future in quantum jump would be crucial for the understanding of the folding process.

One is also forced to ask whether protein can be treated as a dead matter and whether intentional action preferring the generation of macroscopic quantum coherence (number theoretic negentropy) at various scales could play a role in the folding process. This question whether living matter might behave like living matter might look somewhat strange after few decades but at this moment the historical ballast forces to represent it very cautiously.

4.8 Cognitive Evolution As Self-Organization Of Association Sequences

Before the emergence of zero energy ontology cognitive evolution was regarded as a self-organization of association sequences. Association sequences can develop not only the ordinary space-like quan-

tum entanglement but also combine to form longer association sequences having quantum entanglement in time direction. The emergence of association sequences characterized by increasingly larger value of p-adic prime corresponds to the development of larger coherent cognitive units. The formation of association sequences of association sequences corresponds to the formation of cognitive slaving hierarchies. The replication of association sequences provides a geometric realization for the idea of ideas as living organisms.

In zero energy ontology association sequences are replaced with space-time sheets with CDs and the fractal hierarchy of CDs codes for the non-determinism of association sequences. In zero energy property the replication of these states is expected to be easier than in positive energy ontology. This encourages the interpretation in terms of memes. One can assign to these states representations of logic rules in accordance with the idea that physical world forms a cognitive representation for the laws of physics.

4.9 Brain As A Self-Organizing Quantum Spin Glass

The plasticity of brain is consistent with the identification of brain as quantum spin glass. In this picture the evolution of sub-selves/mental images is a dissipative self-organization process leading to some asymptotic self-organization patterns which correspond to the valleys of the spin glass energy landscape of brain. One can understand development of memories, habits, skills and even fix idees as a quantum self-organization based on Darwinian selection of sub-selves having nerve pulse patterns and synaptic strengths as neural correlates.

The crucial element of the self-organization is external energy feed making possible interesting self-organization patterns. Nerve pulse pattern is analous to an external energy feed and the propagation of nerve pulse could indeed induce energy transfer inducing self-organization in the cytoplasma just below axonal membrane. The gel-sol phase transition accompanying nerve pulse conduction could define the self-organization pattern induced by the conduction of the nerve pulse along axon. Nerve pulses affect the postsynaptic cell: typically excitation or inhibition is in question. The interpretation is again that the incoming nerve pulses push and pull the postsynaptic cell in different directions in spin glass energy landscape and in this manner cause frustrations typical for spin glass like systems. Also frequency and time codings and the lack of a precise neuronal code are consistent with this.

A flow of cytoplasma and of lipids of cell membrane is induced by the conduction of nerve pulse. If DNA as topological computer model makes sense in the case of axons, this would induce a braiding of the magnetic flux tubes assumed to connect DNA to cell membrane and thus quantum computation and memory representation for the conduction of nerve pulse pattern.

In TGD framework nerve pulse patterns provide a symbolic representation of the sensory experience whereas sensory qualia are located at sensory receptors. The back projection from brain is essential in building the sensory percepts as asymptotic self-organization patterns via the dialog between brain and sensory receptors. Neural pathways would give rise to characteristic self-organization patterns providing symbolic representations for the sensory input. Quantum spin glass paradigm combined with the notion of the geometric memory leads to a general model of long term memories circumventing the basic difficulty of the neural net models of long term memory related to the fact that long term memories identified as synaptic strengths tend to be destroyed by the learning of new memories. This view about memory also resolves the objections against the idea that sensory receptors are loci of sensory qualia.

4.10 About The Notion Of Quantum Criticality In TGD Framework

Quantum criticality is a fundamental physical principle of TGD dictating the classical and also quantum dynamics so that it deserves a separate discussion from the "modern" viewpoint inspired by what has happened in TGD during more than decade after writing the text above "classical" view. According to the "classical" view, the value of Kähler coupling strength - the only parameter of theory - is fixed as the analog of critical temperature. In order to characterize the critical degrees of freedom one must say something about the Kähler metric of WCW [K19].

1. The matrix defined by the second order derivatives of Kähler function with respect to WCW coordinates is degenerate as is also the WCW Kähler metric defined by a subset of these

derivatives ($G_{K\overline{L}} = \partial_K \partial_{\overline{L}} K$ is the defining formula of Kähler metric in complex coordinates in terms of Kähler function K).

The reason for the degeneracy is that WCW metric depends on real zero mode coordinates, which do not appear as differentials in the line-element. These coordinate directions of WCW correspond to non-quantum fluctuating classical degrees of freedom not contributing to WCW Kähler metric. The proposed generalization of quantum measurement theory assumes that zero modes are analogous to classical variables defining say the position of a pointer of a measurement instrument and that they are in 1-1 correspondence with the outcomes of quantum measurements in quantum fluctuating degrees of freedom and give rise to quantum classical correspondence.

2. Quantum criticality would corresponds to a situation in which maximum of Kähler function (defining most probable space-time surface in their quantum superposition) corresponds to a Kähler metric for which some elements of Kähler metric approach zero so that the rank for the matrix defined by the non-vanishing components of the Kähler metric is reduced. The resulting degrees of freedom would be effectively zero modes inside the critical manifold but not elsewhere. The criticalities would define an infinite hierarchy analogous to the finite hierarchy of criticalities for finite dimensional catastrophes Thom's catastrophe theory (see `http://tinyurl.com/fpbsm`) [A4]: cusp catastrophe is the simplest non-trivial example.

3. At the level of WCW geometry (see `http://tinyurl.com/ycqyk49f`) conformal symmetry algebras [K27] defining the infinite-dimensional symmetries of TGD Universe - call them with generic name A - this hierarchy could have very elegant representation. The elements of conformal algebra are labeled by integer plus other quantum numbers so that one can write the element of algebra $a_{n,\alpha}$. Critical sub-manifolds woud correspond to sub-spaces of WCW for which the elements $a_{nk,\alpha}$ of sub-algebra A_n (k is integer) annihilate the states or creates zero norm f states from them. Here n is a non-negative integer characterizing the critical manifold. Critical manifolds would be in 1-1 correspondence with non-negative integers n. If n_1 divides n_2, the critical manifold Cr_{n_2} belongs to Cr_{n_1}.

4. In the phase transitions between different critical manifolds some quantum fluctuating degrees of freedom become local zero modes in the sense that their contribution to WCW metric at a given point of WCW vanishes at criticality. Also the reverse transformation can take place.

The progress that has occurred since 2005 raises some interesting questions.

1. Criticalities form a number theoretic hierarchy and primes define "prime criticalities". Does this mean that the primes dividing integer n define the possible p-adic topologies assignable to criticality defined by n?

2. The hierarchy of effective Planck constants is labelled by integers and giving integer n corresponds to n-furcation made possible by the failure of strict determinism for Kähler action. Could this integer correspond to the integer defining the criticality? Criticality is indeed accompanied by non-determinism realized as long range fluctuations.

3. Causal diamonds have size scales coming as integer multiples of CP_2 scale. Does this integer relate to the integer defining criticality?

4. The condition that the n characterizes finite measurement resolution in the sense A_n annihilates the physical states everywhere would de-localize the critical states outside the critical manifold. Does this mean that also finite measurement resolution is characterized by integer.

5. How the 4-D spin glass degeneracy due to the huge vacuum degeneracy of Kähler action implying breaking of strict determinism relates to quantum criticality?

These suggestive connections suggest that integer arithmetics are coded directly to the hierarchy of criticalities and also be a basic characteristic of consciousness. This would give additional piece of support for the vision about physics as a generalized number theory (see http://tinyurl.com/y86lo57g) [K31].

5 Could TGD Provide Justification For The Ideas Of Rupert Sheldrake?

Rupert Sheldrake [I4] has developed a theory of learning and memory based on the concepts of morphic fields and morphic resonance. In the following I describe briefly the theory of Sheldrake and consider a TGD variant of of the theory.

5.1 Sheldrake's Theory

The following summarizes very briefly the basic ideas of Sheldrake's theory.

1. The basic hypothesis is that learning occurs also at the level of species. If some individuals of the species have learned some habit then it becomes easier for the remaining individuals of the species to learn the same habit. The individuals who learned the habit first need not even live anymore or can live in a distant part of the world. Collective learning is claimed to occur in a morphic resonance analogous to a phase transition leading from a small seed of individuals with new habit to a population having the same habit. Morphic field provides a representation for a habit and resemble the concept of meme in this respect. Sheldrake states the basic assumptions of his theory in the following manner:

   The idea is that there is a kind of memory in nature. Each kind of thing has a collective memory. So, take a squirrel living in New York now. That squirrel is being influenced by all past squirrels. And how that influence moves across time, the collective squirrel-memory both for form and for instincts, is given by the process I call morphic resonance. It's a theory of collective memory throughout nature. What the memory is expressed through are the morphic fields, the fields within and around each organism. The memory processes are due to morphic resonance.

2. Sheldrake defines morphic fields in the following manner:

   Basically, morphic fields are fields of habit, and they've been set up through habits of thought, through habits of activity, and through habits of speech. Most of our culture is habitual, I mean most of our personal life, and most of our cultural life is habitual. We don't invent the English language. We inherit the whole English language with all its habits, its turns of phrase, its usage of words, its structure, its grammar.

   "Alike likes alike" rule states that learning induces learning only in the members of *same* species. This suggests that the morphic fields correlate strongly with genome.

4. Sheldrake represents the learning of language as a good example of morphic resonance.

   Occasionally people invent new words, but basically, once we've assimilated it, it happens automatically. I don't have to think when I'm speaking, reaching for the next word. It just happens, and the same is true about physical skills, like riding a bicycle, or swimming, or skiing if you can ski, these kinds of things. So I think the more often these things happen the easier they become for people to learn. Things like learning language have happened overwell, we don't know how long human language has been around, at least 50, 000 years, so there's a tremendously well-established morphic field for language-speaking. Each particular language has its own field which is usually established over centuries at least.

5. Sheldrake notices also that morphic resonance and morphic fields are not all what is needed to understand evolution.

   The whole idea of morphic resonance is evolutionary, but morphic resonance only gives the repetitions. It doesn't give the creativity. So evolution must involve an interplay of creativity and repetition. Creativity gives new forms, new patterns, new ideas, new art forms. And we don't know where creativity comes from. Is it inspired from above? Welling up from below? Picked up from the air? What? Creativity is a mystery wherever you encounter it, in the human realm, or in the realm of biological evolution, or of cosmic evolution. We know creativity happens. And then what happens is a kind of Darwinian natural selection. Not every good idea survives. Not every new form of art is repeated. Not every new potential

instinct is successful. Only the successful ones get repeated. By natural selection and then through repetition they become probable, more habitual.

5.2 TGD Based Interpretation Of Morphic Fields And Collective Memory

I have proposed for more than decade ago a TGD based formulation justifying the basic ideas of Sheldrake to some degree. The recent formulation involves several new elements. Zero energy ontology implying that WCW ("world of classical worlds") spinor fields allow an interpretation as memes or morphic fields, the model for living matter in which the notion of magnetic body plays a key role, and the model of DNA as topological quantum computer allowing to identify the morphic quanta relevant for living matter.

5.2.1 WCW spinor fields

In TGD framework zero energy states correspond to the modes of completely classical WCW spinor fields with fermionic second quantization at space-time level having purely geometric interpretation at the level of WCW . The analysis of the degrees of freedom involved demonstrates that WCW spinor fields are analogous to ordinary quantum fields but hav infinite number of components.

1. WCW decomposes to a sub- WCW s association with unions of causal diamonds (CDs). Individual CD is partially characterized by the moduli defined by the positions of its upper and lower tips. The proposal is that the temporal distances between the tips are quantized in octaves of CP_2 time scale and thus coming in good approximation as secondary p-adic time scales for primes very neary to power of two. The most general proposal is that also the position of the upper tip at proper time = constant hyperboloid of future light-cone M^4_+ is quantized for positive energy states. For negative energy states this happens to the lower tip. This disrete set would provide a discretized quantum version of Robertson-Walker cosmology with discretized lattice like structure replacing the continuum. The interpretation would be that lower tip corresponds to the usual Minkowski space-time of special relativity and the discretized position of upper tip to the space-time of cosmology. This implies very strong predictions such as the quantization of cosmic redshifts which is indeed observed [K30]. Similar quantization would take place in CP_2 degrees of freedom for either tip. WCW spinor fields for single CD would depend on these moduli and for positive (negative) states one would have wave functions in the space formed by sub- WCW s with wave function basis consisting of products of plane waves in M^4 with a wave function in the discrete subset of $M^4_\pm$. These degrees of freedom generalize those of a quantum field in Minkowski space.

2. The notion of generalized imbdding space forces to assign to a given CD a selection of quantization axis of energy and spin which in the case of M^4 boils down to a choice of a preferred plane $M^2 \subset M^4$ plus a choice of time direction (rest system). In the case of CP_2 the choice of quantization axes of color isospin and hypercharge means a choice of a homologically trivial geodesic sphere of CP_2 plus preferred isospin quantization axes. The space for possible choices of quantization axis defines additional moduli. The selection of quantization axes in state function reduction means a localization in these degrees of freedom. The space characterizing the selections of color quantization axis represents an example of so called flag manifold. It has already earlier appeared in TGD inspired biology with a motivation coming from the observation of topologists Barbara Shipman that the mathematical model for honeybee dance leads naturally to the introduction of this space. Shipman speculated that quarks have some role in biology [A1]. Dark matter hierarchy indeed makes indeed possible scaled up copies of QCD type theory in biological length scales.

3. WCW spinor fields restricted to a CD with fixed moduli have infinite number of bosonic and fermionic degrees of freedom. Spin-like degrees of freedom for these fields correspond to WCW spinors, which describe many-fermion states consisting of quarks and leptons and bosons defined as their bound states. This Fock state is assigned to each 3-surface and the dependence on 3-surface defines purely bosonic ("orbital") degrees of freedom, which can

be coded by using a state basis whose elements have well-defined spin and color quantum numbers. The bosonic and fermionic degrees of freedom are super-symmetrically related.

5.2.2 WCW spinor fields as morphic fields

The interpretation of the WCW spinor fields as memes or morphic fields is encouraged by two observations.

1. Zero energy states have an interpretation as Boolean rules $A \to B$ as well as self-organization patterns. Fermion number 1 and 0 for a given fermion mode represents values of one particular Boolean statement in positive *resp.* negative part of the state. The instances of A are assigned to the positive energy (initial) state and those of B to the negative energy (final) state and the quantum superposition of the paired instances defines the rule. Since time-like entanglement coefficients define M-matrix, the interpretation as a law of physics coded to the structure of the physical state itself is possible. Fermionic degrees of freedom correspond to the spin indices of WCW spinor fields. Besides this there are "orbital" degrees of freedom in the moduli space for CDs and in the space of deformations of light-like 3-surfaces. It is natural to assign these degrees of freedom to sensory perception.

2. The p-adic description of cognitional action involves a generalization of the notions of number and of imbedding space. The hierarchy of Planck constants means a further generalization of the notion of imbedding space by replacing it with a book like structure. It seems that the discrete intersection of real and p-adic space-time surfaces consisting of rational points (possibly also algebraic points) is crucial from the point of view of consciousness theory. This is true also for the intersection of real and p-adic variants of WCW identified as 3-surfaces whose mathematical representation makes sense in both real and p-adic number fields in preferred coordinate fixed by symmetries.

   The first intersection is expected to be relevant at quantum field theory limit, which involves the replacement of the partonic 2-surfaces with a discrete subset of points carrying quantum numbers. The second intersection is relevant in the full quantum theory. The notion of number theoretic Shannon entropy having negative values makes sense in both intersections since entanglement probabilities must make sense in both number fields so that they are rational or belong to an algebraic extension of rationals. In these intersections of realities and various p-adicities the evolution of memes is expected to take place.

   One manner to understand the special role of rationals and algebraics relies on the observation that rationals represent islands of order in the sea of chaos defined by reals since their pinary expansion is predictable and analogous to a periodic orbit of a dynamical system whereas for a generic real number there is no manner to predict the pinary expansion.

5.2.3 Morphic fields relevant to living matter

All zero energy states have interpretation as memes or quanta of morphic fields in TGD framework. One can however ask what zero energy states are relevant for biological systems.

1. The memes relevant to living matter must have a very concrete connection to biology. DNA as topological quantum computer hypothesis states the magnetic flux tubes connecting nucleotides to lipids of nuclear and cell membranes define braid strands needed to realize topological quantum computations. Nerve pulse patterns induce fluid flows of cytoplasma and of lipids in turn inducing time-like braidings defining running topological quantum computation programs and their memory representations as space-like braidings in the final state. These programs living (in very literal sense) in the brains of geometric future and past define a 4-D population of memes. The intronic part of the genome is specialized to topological quantum computations and the time scale in this case can be and must be faster than for the chemical gene expression. The repetitive character of many intronic DNA sequences regarded as evidence for their junk character does not mean any restriction for topological quantum computation.

2. The notion of magnetic body has a central role in TGD inspired biology. Magnetic body has an onion-like fractal structure and astrophysical size with wavelength of EEG wave defining the size scale of the magnetic body with which it is associated. Magnetic body acts as as an intentional agent using biological body as a motor instrument and sensory receptor. Magnetic body receives sensory and other information from biological body through EEG and its fractal counterparts and controls biological body via EEG type signals sent to the genome, where they induce chemical or electromagnetic gene expression. This allows to imagine also a mechanism of collective learning. The spatio-temporal nerve pulse patterns defining topological quantum computations are mediated via EEG and its fractal counterparts to the magnetic body of organism and from it to the magnetic body of another organism. The magnetic body of Earth - magnetic Mother Gaia- could serve as a relay station and Schumann resonances and alpha band could allow broadcasting of the nerve pulse pattern to a large number of magnetic bodies of organisms. From the latter magnetic body the field representation of nerve pulse pattern would induce via EEG type signal from magnetic body to the receiver genome the original nerve pulse pattern in the brain of the receiver. Nerve pulse patterns would be quite generally induced by magnetic bodies via appropriate part of the intronic genome as electromagnetic gene expression. This mechanism could be also involved with telepathy and remote mental interactions.

3. Morphic resonance and alike likes alike rule can be understood from the condition that the intronic parts of genomes must be similar enough to allow the realization of the topological quantum computation. Also neuronal pathways involved must resemble each other in order that spatial nerve pulse patterns can be re-produced faithfully enough. Also the evolutionary levels must be more or less the same in order that the topological quantum computation has same meaning for the receiver and sender. Therefore the collective memory might be restricted to the level of species. This might be however too strong an assumption. For instance, shamanism could represent an example of interspecies memory. The TGD based view about memory allows also the possibility to use the memories of the already deceased members of species which can in principle continue to exist in the geometric past.

4. The general vision about evolution as recreation of the quantum Universe implies that creativity is in very literal sense a basic aspect of TGD Universe. The U process represents the creative aspect of consciousness generating quantum super-position of Universes from which generalized state function reduction process selects the outcome. Both volitional actions and sensory perception involves the selection but quantum statistical determinism implies that sensory percepts are usually predictable.

5.2.4 Collective memory, geometric memory and self hierarchy

The notion of species memory is rather radical departure from the teachings of standard neuroscience so that TGD based view about memory deserves a separate discussion.

TGD predicts infinite hierarchy of selves and if this hierarchy has levels between living systems and entire universe, the idea about collective memory makes sense and generalizes to an entire hierarchy of them.

Geometric memory provides a promising candidate for the mechanism of a long term memory. Geometric memory is made possible by the fact that self can have multitime experiences such that the space-time sheets associated with various values of the geometric time give contributions to the experiences and past contributions are experienced as memories. In zero energy ontology these space-time sheets are associated with sub-CDs of CD associated with self. Both time-like entanglement between sub-CDs of recent and past implying sharing and fusion of mental images an classical communications between these CDs are possible and give rise to episodal memories (direct re-experiences) and symbolic memories.

Since both geometric past and future change in each quantum jump these memories are not stable: long term memories are certainly unreliable. The memory formation mechanism of brain however tends to stabilize these memories. There is in principle no upper bound for the span of the geometric memories and one can consider the possibility of racial memory and even species memory. Under suitable conditions organism could be able to have the space-time sheets of the geometric

past as its sub-selves and experiences these memories. Thus geometric memory is consistent with Sheldrake's claims and to some degree supports them.

5.2.5 Language learning and morphic resonance

The easiness of children to learn language could have explanation in terms of morphic resonance. The strong quantum entanglement between the child and parents, especially mother, could make the morphic resonance possible in the proposed sense. One can even imagine that mother's magnetic body directly induces nerve pulse sequences representing linguistic memes in the brain of child.

One can of course wonder why it is so difficult for the older people to learn language. Do we force us to learn the language at reflective level although it could occur at proto-level also. Older people learn rules but find difficult to apply them whereas child learns to apply the rules without learning the rules themselves. Are older people so far from quantum criticality that the large fluctuations leading to the generation of the new level of self-organization are not possible anymore? The reason could also relate to the degeneration of the magnetic flux tubes circuits due to ageing so that new topological quantum computation programs are not establishes so easily anymore.

5.2.6 Self hierarchy, bio-feedback and sociofeedback

Magnetic bodies act as intentional agents in the proposed model. They form also a hierarchy analogous to master-slave hierarchy. The proposed mechanism of collective learning involves the magnetic body of Earth in an essential manner. Also magnetic bodies of larger structures could be involved: there is indeed evidence that remote cognition involves galactic magnetic fields [K26] , [J2].

The phenomenon of bio-feedback provides direct evidence for this phenomenon in a length scale familiar to us. By monitoring the behavior of say single neuron, it is possible to learn to affect the behavior of neuron volitionally. No knowledge about how this happens is needed: the volition is enough. The explanation would be that the information provided by the monitoring goes to the magnetic body of the person which reacts by sending control signals to the brain. The already existing magnetic flux tube connections guarantee that the volitional act affects the neuron. The possibility of biofeedback suggests the possibility of socio-feedback and feedback even at the level of species and entire biosphere.

An interesting test for the idea that people very close to each other could directly affect the brain function of each other would be biofeedback in which subject person tries to affect the behavior of a neuron of a close friend or relative. Mother and child might be an optimal choice in this respect.

6 Sheldrake's Morphic Fields And TGD View About Quantum Biology

I received two books of Rubert Sheldrake as a gift from Mark McWilliams, who has for years helped me by reporting about problems at my homepage and sending links to interesting articles. The titles of the books of Sheldrake are "*A new Science of Life: the Hypothesis of Formative Causation*" [I4] and "*The Presence of the Past: Morphic Resonance and Habits of Nature* " [I5]. The titles reveal the two basic notions underlying the vision of Sheldrake.

What makes the study of the books so rewarding is that Sheldrake starts from problems of the existing paradigm, analyzes them thoroughly, and proposes solutions in the framework provided by his vision. There is no need to accept Sheldrake's views, just the reading of his arguments teaches a lot about the fundamental ideas and dogmas underlying recent day biology and forces the reader to realize how little we really know - not only about biology but even about so called established areas of physics such as condensed matter physics. These books are precious gems for anyone trying to build overall view.

The discussion of the previous section is several years older than the discussion of this section and I have not checked whether the two views are consistent and whether I am repeating same

statements. This is not solely due to my laziness: the me of year 2004 is not the me of year 2011 and I feel that it is useful to allow the two prophets to express themselves freely: the reader can use both inputs besides Sheldrake's own excellent representations to form her own views. The reader should take these sections as jazz improvizations using the same theme rather than expressions of last will.

6.1 Habits Of Nature

The idea that Nature would have habits just as we do is probably one of those aspects which generate most irritation in physicalists believing that Nature is governed by deterministic laws with classical determinism replaced with quantum statistical determinism. Sheldrake is one of those very few scientists able to see the reality rather than only the model of reality. Morphic resonance would make possible to establish the habits of Nature and the past would determine to high extent the present but on organic manner and in totally different sense as in the world of physicalist.

6.1.1 Some problems of biology

It is instructive to consider as an example the first chapter of the book about formative causation discussing the basic problems of biology. Shelrake's proposal is that something more than organic chemistry is needed to understand living systems. He assigns to this something the notions of formative causation, morphic fields, and morphic resonance. In the following brief summary I refer also to some TGD inspired proposals for the needed new notions as remarks.

1. First Sheldrake discusses first the standard mechanistic view which does not accept any "vital factors" or goal directedness but just the blind chemistry based on random change and choice but implicitly brings in these factors as genetic programs. In neuroscience one introduces computer paradigm without realizing that computers by definition are systems whose goal is to solve a problem mechanically. The goal is of course not posed by the computer but by its builder. One important aspect of the vision is the idea about chemically operated switches (they could be non-coding DNA sequences) switching genes on and off. Morphogenesis could be seen as differentiation in which genes are switched on and off to produce a particular body part. A fairy tale in which the hero receives a key to open the next door to receive a new key to open... is very attractive metaphor for morphogenesis as a chemical process. This idea is very powerful but might not be all that is needed. The question popping up automatically is "Who turns the switches on and off?".

   Note that assigning the information about organism to its genome is very near to the idea about organism as hologram. More generally, the idea about germ cell as a hologram representing some essential aspects about the organism is very attractive. There would no need to assign this information to genes or DNA alone. This would be more refined form of the naive idea that there is some kind of miniature representation of the fully developed organism realized in germ cells level.

2. Sheldrake discusses four problems of morphogenesis.

   (a) The first problem of morphogenesis is its stability - one speaks about regulation. In some experiments second cell of two-celled embryo is destroyed but the embryo still develops to a full organism albeit with abnormally small size. One can also fuse several embryos and they develop to single abnormally large organism. This suggests goal directedness. In the fairy tale the hero must overcome all kinds of misfortunes while trying to find the door to which the newest key fits.

   Development as a self-organization process depending only weakly on initial conditions might help to understand goal directedness as something only apparent. The basic aspect of self-organization indeed is the weak dependence on initial values: the reason is that dissipation in presence of external energy feed leads to a highly unique outcome. In absence of energy feed all motion ceases! Note however that the notion of self-organization should be also defined precisely. Should we adopt a purely classical view

about self-organization based on non-equilibrium thermodynamics or about its quantum counterpart?

(b) Second problem is how completely new structures (eyes, heart, brain, body parts, ...) emerge during morphogenesis. It is very difficult to understand this in terms of genetic code alone. Genes seem to be too rigid structures. In the vision of Sheldrake's (and TGD vision) genes are only the hardware. Also software is needed. The fairy tale about hero with the keys comes in mind. Maybe the keys would be represented by the genes serving as switches activating or de-activating genes? This could mean a highly flexible chemical program since each reaction could proceed only when the preceding reactions have proceeded.

But is morphogenesis only a realization of an existing plan or a genuinely creative process? What happens when something genuine new emerges in the genuine evolutionary process leading to full grown organism? Could non-equilibrium thermodynamics help to conceptualize the situation? In non-equilibrium thermodynamics one has several flow equilibria and the emergence of something genuinely might be seen as emergence of a new flow equilibrium. But is non-equilibrium thermodynamics enough? Is quantum coherence in biological length scales necessary in order to understand the creative aspects of morphogenesis.

(c) Regeneration is the third problem. Full grown organism is able to regenerate large damaged parts of the organism. Also small pieces of organism can develop to a full organism. The brain of salamander can be split into pieces and these pieces can be shuffled randomly: yet the development leads to a salamander with a healthy brain. Could one regard organisms as hologram like structures with pieces of organisms representing in a good approximation the entire organism?

The recent discoveries showing that the amount of DNA does not correlate much with the evolutionary level force to conclude that DNA alone cannot code for the entire organism. So called homeobox genes thought originally to code the phenotype of the organism are essentially same for all organisms so that something else is definitely involved. Could genetic code combined with self-organization and hologram paradigms be enough? The answer depends much about what we mean with self-organization and with hologram. Or should one interpret DNA as hardware and assume software as something unknown to the recent day physics?

(d) Reproduction is the fourth problem. It is also clear that a kind of fractal pattern is involved in the sense that the reproduction is scaled up variant of DNA replication and induced by the replication. The idea that everything reduces to DNA replication is attractive but do we really understand DNA replication at the level of first principles? Could it be that replication in some sense reduces to some fundamental process of Nature not yet identified in what we are used to call fundamental physics? Sheldrake suggests that morphic resonance favors the formation of almost copies and therefore replication. Morphic resonance is analogous to the tuning of radio but why this tuning should take place spontaneously? What principle could imply it?

Remark: In TGD framework the notion of generalized Feynman diagram leads to the idea that replication is indeed a key aspect of quantum physics. The 1-D lines of ordinary Feynman diagrams are replaced by 3-D light-like surfaces identifiable as orbits of partonic 2-surfaces. These 2-surfaces can have arbitrarily large sizes and one could assign them even to cell membrane. By strong form of holography these 2-surfaces are very much like holograms representing 4-D physics almost faithfully (the precise characterization of "almost" would require a more technical language telling not much for a non-mathematician). In the vertices of generalized Feynman diagrams the ends of the light-like 3-surfaces are glued together along partonic 2-surfaces. The simplest $1 \to 2$ vertex representing particle decay or emission has interpretation as a replication of partonic 2-surface. The quantum states associated with the resulting partonic 2-surfaces are not identical but geometrically replication is in question.

Could one identify this process as the fundamental replication process? If so, then replication in living matter would be only special case of a universal process present

already in particle physics and distinguished from it only by the enormous complexity involved. This would be of course only the fundamental mechanism of replication. One must also explain why replication occurs.

The idea about self-tuning is highly attractive as a partial explanation for why replication takes place. What tuning makes possible is information transfer and in TGD framework there is temptation to explain tuning in terms of Negentropy Maximization Principle (NMP) [K18].

3. The understanding of morphogenesis is difficult but should be child's play as compared to the understanding of behavior. Inherited behavioral patterns - instincts- define the first hard problem. Information is transferred between generations and saying that genes -that is organic chemistry- code this information does not help much. Second problem is the goal directnedness of the animal behavior: animals can modify their behavior when something prevents the achievement of the goal. Behavior can be also intelligent: animals can learn new behavioral patterns. This is not in accordance with the idea that behavior is hardwired in the genome.

   Remark: Physicist might see behavioral patterns as 4-dimensional patterns resulting in self-organization: characteristic time evolutions. But does this kind of notion make sense? Does it assume additional time? Usually it is thought that self-organization corresponds to an evolution of a 3-D pattern rather than 4-D one. Perhaps TGD based view about time is needed. The experienced/subjective time is assigned to conscious experience identified as a sequence of quantum jumps defining the basic building brick of conscious existence. Subjective time is not identified with the geometric time although they relate closely to each other- at least in standard wake-up consciousness [K2].

   Each quantum jump replaces 4-dimensional pattern with a new one and the self-organization patterns in this 4-D sense could correspond to behavioral patterns whereas approximately static 4-D patterns reducing to 3-D patterns would represent morphologies. There are quantum jumps within quantum jumps so that the outcome is a fractal pattern having also interpretation as a self hierarchy. This gives one possible meaning for the "presence of the past" in the title of the second book of Sheldrake. Living matter would be essentially 4-dimensional and the goal directed behavior based on memory would reflect this 4-dimensionality: goal in general case 4-D pattern. In zero energy ontology the arrow of geometric time need not be always the same and signals propagating to geometric past are key element of TGD based view about memory, intentional action, and metabolism [K2]. This would represent a new element distinguishing TGD view from Sheldrake's view.

4. The notion of evolution is also problematic. Can microevolution within species explain the evolution of species itself? Or do sudden discontinuous jumps take place? Could evolution involve a genuinely creative aspect? Is there any hope that a choice among random mutations could explain the emergence of a new highly organized morphological or behavioral pattern? Note that exactly the same problem was encountered at the level of morphogenesis and development of individual. Only the time scale is different.

   Also adaptive convergence looks mysterious: same structure emerges at different sides of Earth simultaneously. For instance, the emergence of large primates leading to humans took place at widely separated places. This forces to ask whether morphic fields are involved and make entire species an organism so that the evolution is non-local process. This also relates to the idea about bio-system as a hologram. In Sheldrake's vision the simultaneous emergence of new species would reflect the holistic evolution of the entire biosphere.

   Remark: In TGD framework the emergence of a completely new structure could involve a phase transition introducing a new level to the hierarchy of Planck constants assignable to a given species. Since the value of Planck constant serves as a measure for evolutionary level, something genuinely new would emerge in the process. The maximal value of Planck constant could allow to characterize the evolutionary level of cell or neuron, organ, organism, population, and even species. The understanding of dark matter would become a prerequisite for the understanding of the living matter.

5. Sheldrake discusses also the origin of minds and parapsychology in this chapter. Morphic fields could obviously relate to mind and make also possible remote mental interactions.

   Remark: In TGD framework the theory of living matter involves quantum theory of consciousness as an essential part and the notion of magnetic body carrying dark matter - in particular dark photons- is a good candidate for the counterpart for the morphic fields.

6.1.2 The notion of morphic field

The notions of morphic field, morphic resonance and formative causation are very interesting and there is considerable support for Sheldrake's vision. The initial motivation for the notion of morphic field was that the same skill discovered by populations located in different parts of the world. Theory leads to idea about learning and memory at the level of species and also to an idea about gene expression at level of species in which remote activation of genome takes place using morphic signals from past. Genome would be the hardware and morphic fields the software.

Shelrake uses TV as an analogy.

1. Morphic fields would be analogous to radio waves carrying information (say in terms of amplitude or frequency modulation) and could code genetic information and genetic programs. Genes act as antennas and the details of gene expression depend on the value of the tunable antenna frequency. When the antenna frequency changes, the received signal changes and gene expression changes too. Adaptation could correspond to a change of antenna frequency in turn modifying gene expression as a response to a modified morphic signal. Also epigenetic inheritance could relate to the activation of genes acting as switches for genes. Mutations would correspond to changes in the genome analogous to the changes in the hardware of TV.

2. The tuning to some frequency would be the basic process in brain and is known as entrainment. In fact, even mechanical systems such as clocks are known to entrain to a common rhythm. The physical mechanism for this is not well-understood. Perhaps the entrainment is a fundamental physical process having explanation in terms of NMP (Negentropy Maximization Principle [K18]. If so, the idea about tuning would be a generalization of what we already know to take place.

3. The idea about morphic signals from past affecting the gene expression in the genomes of the same species would explain many strange findings discussed by Sheldrake. Morphic signals could silence or activate genes. If there are genes inducing modifications of DNA, then morphic signals could even modify the genome. Species would be kind of hologram: each member would be a representation for the species and genetic expression would be collectively determined.

4. What kind of morphic field patterns are possible? A natural proposal is that DNA sequences can be coded to the spatiotemporal patterns of morphic fields. TGD based realization of morphic fields is one possible realization of his condition. In this case frequency which for a fixed photon energy is coded by the value of Planck constant matters as also the connection defined by magnetic flux tube between molecules involved.

   Modern radio-communications code the data to bit sequences represented as temporal patters of the radio wave. Could the temporal patterns of morphic fields be important and could one imagine some codes? Among other words this would make possible selective communications using passwords. For resonance common antenna frequency would be enough and the experience from computer communications suggests the possibility of a coding based on the representation of bits as pulses but many other codes can be imagined.

   Remark: If certain carrier frequencies carry information, NMP would explain why self-tuning occurs.

Sheldrake proposes speculative but fascinating applications of morphic resonance in somewhat unexpected contexts.

1. The fact is that even the formation of simplest crystals is poorly understood for the simple reason that the calculations needed are extremely complex. Simplified models represent

larger numbers of crystal structures and it is difficult to understand why only very few crystal forms are realized in Nature. The standard professional folklore among chemists is that once some new chemical compound has been been crystallized for the first time its crystallization becomes gradually easier and easier. The obvious looking explanation for this is not however obvious. Could morphic fields select one of the many possible crystal forms? Could crystallization to a specific crystal form be a habit of Nature?

2. Protein folding is second mysterious phenomenon. The mysterious aspect of the process are its deterministic character and its rapidity. The number of possible foldings is astrophysical and one can expect a huge number of local minima of free energy and therefore a huge number of thermodynamically stable foldings. Sheldrake suggests that the interaction with the morphic fields of the environment is part of the process and makes the folding a learned habit.

6.1.3 Inheritance and morphic fields

Sheldrake discusses inheritance and suggests that besides genetic inheritance and epigenetic inheritance also morphic fields could give rise to a new kind of heritance. The basic question is whether the acquired characteristics resulting from adaptation could be inherited in some manner. This is usually known as Lamarkcian inheritance of acquired characteristics. One can also ask whether adaptations perhaps allowing interpretation as mutations of morphic fields- software- could be transformed to mutations - modifications of the hardware.

1. Epigenetics (see `http://tinyurl.com/4xpwcm`) [I1] is the study of the mechanisms inducing changes in gene expression without change in DNA itself. Differentiation of cells is the most obvious example of this kind of process. The suppression of gene expression without altering the DNA sequence of altered genes by DNA methylation or histone deacetylation is one mechanism of epigenesis. Epigenetic changes are preserved in cell division.

   Also epigenetic inheritance is possible. This requires that the modification of genes -say methylation of DNA - takes place also at the level of eggs and sperm. For instance, it has been discovered that the effects of famine and diseases can echo to the next generations. The mechanism making this possible is not well-understood and one can ask whether morphic resonance is involved and affects also the eggs and sperm. If so, one could speak about inheritance of acquired characteristics.

2. The notions of dominating and recessive gene (see `http://tinyurl.com/aqvyae`) are familiar for everyone from school days but very few of us has asked what makes the gene dominant or recessive. Or whether both genes (alleles) could affect the phenotype (say color of the flower) to some degree. Usually the chromosomes appear as non-identical pairs and the members contain corresponding genes (alleles) coming from the parents. These genes are not identical so that they can code different trait for the same phenotype. The question is what chooses which allele is expressed. The usual answer is that the "normal" gene is expressed. But what makes the gene "normal" ?

   The proposal of Sheldrake is that morphic signals from past force the expression of the normal gene. The normal gene is the one expressed also in the past and for these reason the signal from past supporting the expression of this gene dominates. Gene expression is to some degree like a habit due to majority democratic decision of a 4-D society. It is also possible that both alleles determine the trait. Sheldrake's interpretation would be that in this case both morphic signals can be realized and the outcome is a mixture of traits. Different cells have in this case different habits.

3. Sheldrake discusses also what is known as genetic assimilation discovered by Waddington in his study of fruit files. Fruit flies are subjected to external stimuli and as a result develop abnormal phenotypes. What happens that when external stimuli are absent the abnormal phenotype still appears. One can consider several explanations.

   (a) Waddington explains this in terms of canalized pathways of development which he calls chreodes. Abnormal chreodes would be so stable that the absence of stimulus originally inducing them would not affect the situation.

Remark: In TGD framework chreods could correspond to 4-D self-organization patterns depending only weakly on the initial conditions.

(b) Epigenetic inheritance could explain the phenomenon.

(c) Also morphic resonance could explain the finding. The morphic signals from previous generations are present and the net signal would favor the continuation of abnormal gene expression. Indeed, Mae-Wan Ho demonstrated that a strain of flies not subjected to the treatment at all also exhibited the abnormal phenotype in absence of the stimuli. Gradually however the normal phenotype wins. Morphic resonance explains this finding whereas epigenetic inheritance fails to do it.

4. Adaptation to an external stimulus (such as X-rays, come chemical, unusual temperature....) can produce similar effects on phenotype as a genuine homeotic mutation (say the replacement of antenna of fruit fly with wing). Why mutations can produce effects similar to those produced by adaptation? Is it possible that adaptive changes are transformed to mutations by some mechanism?

   (a) Epigenesis is a possible explanation for the change of the phenotype. Epigenetic inheritance does not however explain whyt mutations and adaptations look so similar.

   (b) Morphic resonance would modify only the software but not hardware and could thus explain adaptation. The modification of the antenna frequencies of genes could have profound effects on gene expression in the case that the antenna frequencies of the switch genes are modified. Morphic signal could be even turned off or on.

   Neither explanation for adaptation is able to explain why mutation and adaptation produce similar modifications of the phenotype nor provide a mechanism transforming long term adaptation transform to a mutation. In the case of adaptation the same effect would be produced by using suitable genetic program. Does the finding of the correct genetic modification - addition of a new gene in the simplest case- require trial and error process? How the system knows what mutation produces the same effect as the more complex genetic pathway induced by adaptation? How the activation of this pathway could favor the selection of mutated genes producing the same effect? The Darwinian answer to the question would be of course "survival of the fittest" but is this process too slow?

   Remark: Later a TGD inspired mechanism for the transformation of adaptation to mutation will be discussed.

6.2 TGD Inspired Quantum Biology

TGD inspired quantum biology leads to a picture which has quite a lot in common with Sheldrake's vision. The hypothesis are following.

1. There is a hierarchy of conscious entities and therefore also what can be called hierarchy of collective levels of consciousness. One can speak about species as a living and conscious organism. This suggests among other things coherent collective gene expression and one ends up with the notions of super genome assignable to organs and hyper genomes assignable to organisms, populations and even species. Entire biosphere can be seen as conscious living organism.

2. TGD is an attempt to unify real number based physics and p-adic physics for various p-adic number fields interpreted as physical correlates of cognition. One can assign to each p-adic prime a number theoretic entropy making sense when probabilities are rational or even algebraic numbers. The number theoretic entropy can have negative sign and in this case represents genuine information. In the case of negentropic entanglement the interpretation is that entanglement represents information. This information is not about the state of individual subsystem but about the state of the entire entangled system. A kind of abstraction representing a rule with paired states in the superposition representing the instances of the rule.

The proposal is that living systems reside in well-defined sense in the intersection of real and p-adic worlds: in the intersection of matter and cognition. Combined with negentropy maximization principle (NMP) stating the information contents of conscious experience is maximal [K18] this leads to a more general view about quantum jump and state function reduction: state function reduction need not anymore be a random process. NMP could explain why morphic resonance identified as tuning to particular frequencies takes place spontaneously.

3. Non-locality is essential. TGD provides a new view about fields and the relationship between experienced and physicist's time. One outcome is possibility of macroscopic quantum entanglement and also time-like entanglement in macro-temporal scales of order of memory span and time scale of planned action. One can say that any physical system is four-dimensional and for the understanding of living system this four-dimensionality is essential.

4. The identification of dark matter (the dominant portion of matter) as ordinary matter but with (effective) Planck constant equal to integer multiple of and hence larger than ordinary Planck constant, is essential. For large values of Planck constant macroscopic quantum phases are possible even in the scales of order Earth size and would be a crucial element of living matter making among other things quantum entanglement in the scale of species possible. One can indeed imagine the possibility of collective gene expression. Also phase transitions changing the value of Planck constant would play a key role in bio-chemistry. Dark matter indeed plays a key role in the TGD inspired model for living systems.

5. So called topological quantization of classical fields is essential. In particular, magnetic fields correspond to flux quanta which have concrete geometric representations as flux tubes and sheets identifiable as non-trivial topology of space-time in macro scales.

   (a) The notion of magnetic body is in a key role. One can say that magnetic body uses biological body as a motor instrument and sensory receptor. A fractal hierarchy of EEG like radiation patterns makes possible control by magnetic body and communication to it from biological body. Topological field quanta- in particular magnetic body carrying dark matter- plus ordinary inanimate matter make together living matter.

   (b) Also classical electric fields are predicted to be important: living matter is indeed full of electrets. One can consider two kinds of electric fields. In the first case one can have strong electromagnetic (electro-weak) fields although space-time sheet is almost vacuum extremal. In the second case one has far from vacuum extremal and electromagnetic field and color gauge field are proportional to each other. Both situations are expected to be important in biology [K11, K8].

   (c) So called topological light rays ("massless extremals") attached to magnetic flux tubes are in central role [K20]. Topologically condensed dark photons propagate along them and they can be regarded as analogs of laser beams making possible precisely target communications without dispersion and with maximal signal velocity.

6. Morphic fields might allow identification as dark photon signals propagating with light velocity: this implies effective simultaneity. Also genuine simultaneity is possible by quantum entanglement in macroscopic scales. I have proposed a model for remote DNA replication and remote gene expression and even remote modification of genome becomes possible if there are genes specialized to this.

   DNA and also other biomolecules act as quantum antennas receiving and sending "dark" photons. Two molecules communicate and are able to interact when they have same antenna frequency. This is key part of also bio-catalysis and quantum antenna resonance makes it possible for biomolecules to find each other in the dense soup of biomolecules.

7. Genetic code generalizes and has several realizations. One can say that DNA sequences provide names for polar molecules and one can imagine a mechanism which assigns to this kind of molecule a DNA sequence which codes for a protein attaching to this polar molecule. This might be the basic mechanism allowing the immune system to modify itself rapidly as a response to external stimuli such as invader molecules.

6.2.1 The TGD counterparts of morphic fields

Sheldrake does not speak about quantum effects but is well aware that new physics is needed to understand morphic fields. It is indeed clear that one cannot understand morphic fields in standard physics framework. Even standard quantum theory might not be enough since it allows quantum coherence only in atomic and molecular length scales and already now it is known that quantum coherence prevails in longer length scales in living matter.

1. Quite generally, the ordinary classical gauge fields allowing geometrization in TGD framework and their quanta would define could candidates for the counterparts of morphic fields. This would include both electro-weak and color gauge fields and for large values of Planck constants both weak and color gauge fields could have interaction range relevant for living matter. Biomolecules would act as quantum antennas and morphic resonance would correspond to antenna resonance.

2. Magnetic flux tubes carrying dark photons would replace morphic fields. The braiding of magnetic flux tubes would make possible coding of topological quantum computer programs and flux tubes could connect various molecules with same resonance frequencies making them quantum antennas. The changes of Planck constant for the flux tubes would change their lengths and the contraction of the flux tube could bring distant molecules near to each other so that they would participate in common reaction. This would be the basic mechanism of DNA replication, DNA-mRNA transcription, mRNA-amino-acid transcription and other similar processes. One can also imagine remote replication of DNA and remote version of gene expression. Here TGD based view about dark matter predicting that the states of dark nucleons are in 1-1 correspondence with DNA, RNA, tRNA, and amino-acids is of crucial importance since it makes possible for water to realize genetic code so that biological realization would emerge from this more fundamental realization.

3. The fractal hierarchy of magnetic bodies makes possible collective quantum coherent gene expression and perhaps even collective modifications of genome explaining the convergent evolution. One can imagine that the flux sheets traversing through DNA arrange it to flux sheets organizing the DNAs of organs to single coherent whole. Same would apply in the case of organism and perhaps even in the case of group of organisms and of population. I have introduced the notions of super - and hyper genome to describe this idea [K12].

It must be emphasized that the TGD counterpart for morphic fields and morphic resonance would not explain the creative aspects of evolution. Also the TGD based view about quantum jump, zero energy ontology, hierarchy of Planck constants, NMP, and other new notions are needed.

6.2.2 Self-organization and morphic resonance

Consider next the general TGD inspired view about self-organization by the analog of morphic resonance.

1. In TGD Universe one could see morphologies as 3-D static self-organization patterns and behavioral patterns as 4-D self-organization patterns. The signals defined by morphic fields should select these self-organization patterns. Since self-organization patters typically depend only weakly on their initial values (now basically 4-D self-organization patterns replaced by new ones in quantum jumps), morphic fields must select initial values properly. In 4-D situation about which static 3-D situation is special case, frequencies and wave lengths would represent simplest information about the asymptotic self-organization pattern. They would correspond to higher level slowly varying fields serving as effectively external parameters determining the self-organization patterns in shorter time and length scales in accordance with the Slaving Principle of Haken.

2. One can also imagine the morphic resonance mechanism in which molecules act as quantum antennas tuning to each other and forming interacting groups of molecules. The ability of biomolecules to find each other in a dense soup of biomolecules could be based on pre-existing flux tube connections between them. Morphic resonance could be seen as spontaneous self

tuning. Organisms would be like radio receivers spontaneously tuning to frequencies at which the previous generations send information. After this tuning the self-organization would proceed rapidly. In terms of consciousness theory one might say that self at the higher level of hierarchy would turn its sub-selves like we tune radio to a particular wavelength.

But why this tuning would take place spontaneously? One can argue that tuning generates negentropy and in TGD framework the basic distinction between living and inanimate is negentropy. Could the NMP - in some sufficiently strong form- explain why this tuning takes place? What the maximization of the information content of conscious experience [K18] can mean is however not clear. NMP could also relate to how the arrow of geometric time emerges and in sufficiently general form could even explain why the contents of sensory experience is about rather narrow time interval (with duration of about.1 seconds for human sensory perception) [K2].

Tuning to the frequencies or morphic fields realized as antenna frequencies would be the manner to determine in a given scale the initial conditions leading to unique final outcome very rapidly. The hierarchy of Planck constants assignable to flux tubes mediating dark photons signals would allow the dark photons to have same energy -say at visible range- but different wave-length to which flux tube would be proportional to. Kind of Indra's web would serve as space-time correlate for the morphic fields.

Tuning to a particular frequency to maximize conscious information suggests that this particular frequency defines a carrier wave for information transfer. Frequency and amplitude modulations and bit sequences represented as temporal patterns is what comes first in mind as concrete representations of this information. TGD based view about hearing [K11, K24] suggests two basic representations of information corresponding to temporal patterns and frequencies (the inspiration comes from the "left brain talks, right brain sings" metaphor).

3. The explanation of Sheldrake for dominating/recessive genes in terms of morphic resonance implying that normal gene expression is a genetic habit based on majority decision of members of species in the past is very elegant but need not be correct of course!

   If the antenna frequency of the corresponding genes (alleles) in the chromosome pair are same and corresponds to the antenna frequency of either parent, the gene corresponding to this frequency is expressed. Suppose that this frequency corresponds to the same dark photon energy so that the frequencies are inversely proportional to Planck constant so that higher Planck constant would correspond to a lower frequency. Could the lower frequency defined the common antenna frequency for chromosomes so that the parent with larger value of Planck constant would dominate? This option would explain the dominance differently and normal would correspond to the larger value of Planck constant. The mutations favoring the increase the value of Planck constant would be favored. NMP - understood in sufficiently strong sense- would favor the increase of Planck constant quite generally. One must of course be however very cautious in order to avoid systematic use of NMP to fill the holes in the theory.

4. What is the role of magnetic body and of topological quantum computer programs coded by braidings? Certainly this level should be very closely related to morphic fields. The function of introns is not well-understood and the obvious question is whether the flux tubes emerging from introns could be responsible for quantum computer like activities defining the real software [K9, K32]. Is the magnetic body itself genetically coded and does temporal self-organization patterns - behavior - correspond to this coding?

   It is known that the distribution of codons in intronic portion mimic distribution of letters in natural languages. Could the intronic part of the genome code for the magnetic body, in particular its braiding? What is the effect of external perturbations inducing flow of lipids at lipid layers of cell membrane to the braiding. Zipf law (see `http://tinyurl.com/7cbaj`) stating that the frequency of the word of natural language is proportional to its rank defined according to the ordering defined by its frequency of occurrence holds also for artificial words identified as sequences of subsequent intronic DNA nucleotides of fixed length. Does this mean that intronic DNA defines some kind of language.

5. A reasonable guess is that adaptation affects the genetic programs identified as topological quantum computer programs but not DNA and only rarely even genome (as in case of methylation). In mutation the hardware- genome- is affected and the question concerns the mechanism for the transformation of adaptation to mutation. Dark nuclei define representation of the genetic code and the following proposal is a suggestion for how this could happen.

6.2.3 Dark nucleons, genetic code, and its modifications

Dark nucleons represent genetic code in TGD Universe. What could be their role in the gene expression and in the evolution of genome? Cold dark nucleons define a kind of R&D laboratory allowing to test various kinds of DNA sequences.

1. The basic idea is that any polar molecular is covered by an "ice layer" consisting of ordered water. Assume that this layer determines the magnetic body of the molecule. External perturbation such as the feed of energy cuts the hydrogen bonds connecting the molecule to this layer and molecule can temporarily loose its magnetic body. Assume that this process generates sequences of dark nucleons (dark nuclei consisting of dark protons) which correspond to RNA, DNA, tRNA or amino-acid sequences. In this manner polar molecule would get name coded by the dark nuclei. If transcription of this sequence to DNA or RNA exists, it is possible to assign to this sequence DNA sequence serving as a gene coding for a protein which interacts resonantly with the polar polar molecule via the antenna frequencies defined by the cyclotron frequencies of its magnetic body. This would allow to generate a gene coding for gene attaching to the invader molecule.

2. At least in the case of immune system one might think that system is able to perform genetic engineering as a response to molecules invading to the system and I have proposed a mechanism for this. The transcription of dark genes represented as dark nuclei to DNA or RNA could provide a completely new mechanism of modifying the genome of egg and sperm cells since dark nuclei could penetrate cell membrane without difficulty.

3. Could the mechanism assigning to polar molecule a protein attaching to it allow the transformation of adaptation to mutation? If some protein defines a bottleneck step in adaptation, one could imagine that the transcription of the dark nucleon assigned with this protein to a piece of RNA reverse transcribed to DNA could transform the adaptation to mutation. More generally, if some proteins appear as basic steps in adaptive production of the change of phenotype then this process applied to them could produce the desired mutation of DNA.

4. Also collective genetic modifications can be imagined if there are genes inducing standard genetic modifications. Hardware would modify itself. Species could modify itself by using remote or collective expression of this kind of genes. Recall that retroviruses consist of RNA and reverse transcriptase catalyzing the reverse transcription of RNA to DNA in turn yielding the copies of retrovirus via transcription to mRNA and RNA. If RNA era continues in cell nucleus one can ask whether genome is continuously modified by the attachments of reversely transcribed DNAs from pieces of RNA. Reverse transcription has a high error rate.

To sum up, TGD approach would allow physical interpretation for morphic fields making possible remote gene expression and perhaps even remote genetic engineering. The past of species would affect the recent species. Both spatial and temporal non-locality would be key elements of life making possible memory and planned action.

7 Some Considerations Relating To The Dynamics Of Quasicrystals

The dynamics of quasicrystals (see `http://tinyurl.com/67kz3q`) [L2] looks to me very interesting because it shares several features of the dynamics of Kähler action defining the basic variational principle of classical TGD and defining the dynamics of space-time surfaces. In the following I will

compare the basic features of the dynamics of quasicrystals to the dynamics of preferred extremals of Kähler action (see `http://tinyurl.com/ydyo6mab`) [K3].

Magnetic body carrying dark matter is the fundamental intentional agent in TGD inspired quantum biology and the cautious proposal is that magnetic flux sheets could define the grid of 3-planes (or more general 3-surfaces) defining quasi-periodic background fields favoring 4-D quasicrystals or more general structures in TGD Universe. Also 3-D quasicrystal like structures defined by grids of planes can be considered and 4-D quasicrystal structure could represent their time evolution.

Quite recently it has been reported (see `http://tinyurl.com/876lmaw`) that grids consisting of 2-D curved orthogonal surfaces characterize the architecture of neural wiring so that this hypothesis might make sense. This structure would be analogous to 2-D quasicrystal and its time evolution to 3-D quasicrystal.

7.1 The Non-Determinism For The Dynamics Of Quasicrystals Contra Non-Determinism Of Kähler Action

The dynamics of quasicrystals is non-deterministic in the sense that one cannot construct a unique quasicrystal by starting from a finite portion or even D-1-dimensional section of D-dimension quasicrystal thickened to a slice. Four-dimensional quasicrystals would therefore define a non-deterministic dynamics. This dynamics could serve as a geometric correlate for a full non-deterministic quantum dynamics involving also state function reductions. This requires that quantum classical correspondence is generalized so that also non-deterministic aspects of quantum dynamics are required to have geometric space-time correlates. The global empires of the 4-D quasicrystal could be interpreted as self-organization patterns whereas global empires would represent long range correlations.

This is very much analogous to 4-D spin glass degeneracy in TGD framework.

1. In TGD framework the preferred extremals of so called Kähler action define the dynamics of space-time surfaces. Kähler action [K13] is Maxwell action for the gauge field induced from the Kähler form of CP_2. Symplectic transformations of CP_2 act as abelian gauge transformations and therefore leave the induced Kähler form invariant. They do not however leave the induced metric invariant so that the action changes by a contribution assignable to classical gravitation. For vacuum extremals however the symplectic transformations act as symmetries.

2. This implies huge vacuum degeneracy. Every space-time surface for which CP_2 projection is Lagrangian manifold and thus having at most 2-D CP_2 projection has vanishing induced Kähler form and is therefore vacuum extremal: there is infinite number of 6-D vacuum sectors labelled by Lagrangian sub-manifolds of CP_2 transformed to each other by symplectic transformations. These vacuum extremals behave non-deterministically which means an analogy with quasicrystal dynamics and suggests that quasicrystals might define a simplified model for quantal self-organization.

3. Small deformations of these define non-vacuum extremals and It is very conceivable that part of the vacuum degeneracy remains and is manifested as multi-furcations. The number n of branches for a multi-furcation has interpretation in terms of effective Planck constant $\hbar_{eff} = n\hbar$ to which dark matter is assigned in TGD framework. This degeneracy is very much analogous to a 4-dimensional spin glass degeneracy meaning that space-time decomposes to deterministically behaving regions just like spin glass decomposes to magnetized regions with varying direction of magnetization.

4. The interpretation for the situation in TGD framework is in terms of quantum classical correspondence: not only quantum states correspond to space-time geometries as analogs of Bohr orbits but also quantum jump sequences - which according to TGD inspired theory of consciousness define the contents of consciousness - have non-deterministic space-time geometries as geometric correlates. Space-time geometry and topology are like written text providing information about contents of consciousness.

5. Also p-adic topology as effective topology of space-time surfaces and natural topology for the landscape of extrema of Kähler function of WCW defining its Kähler geometry emerges naturally from this degeneracy. In physics obeying effective p-adic topology the counterpart would be short range chaos with long range correlations in the sense that one would have periodicity in the sense that physical states at time time at and $t + kp^n$, $k = 0, 1, ...p - 1$, $n \geq\geq 1$, would be very near to each other. The interpretation in terms of intentional action would be natural.

   One could also imagine of defining the analogs of empires as connected deterministic regions of space-time surface and the analogs of empires would be unions of disconnected components perhaps understandable in terms of p-adicity. Self-organization patterns would naturally correspond to these regions. Many-sheeted space-time would imply fractal hierarchy of self-organization patterns within self-organization patterns.

7.2 The Dynamics Of Quasicrystals As A Model For Fundamental Dynamics Or High Level Symbolic Dynamics?

Stephen Wolfram (see `http://tinyurl.com/6hztdo`) has suggested that cellular automatons could define the fundamental dynamics. It is not difficult to invent grave objections against this view. One of the objections is that this kind of dynamics is based on simple and rather ad hoc rules and applies to a society rather than to elementary particles. It is difficult to circumvent this counter argument.

One can however ask in what scale the symbolic dynamics does emerge? For few years ago my answer would have been "in biological length scales" (genetic code as symbolic dynamics). TGD Universe is however fractal, and this forces to ask whether this symbolic dynamics emerges already above CP_2 scale in some rudimentary form. In any case, even in this case the dynamics of self-organization would not be identifiable as the fundamental dynamics but as analogous to the rules of behavior in society.

The dynamics of quasicrystals brings indeed strongly in mind the dynamics of self-organization patterns prevailing at relatively high level of dynamical hierarchy. Symbolic dynamics prevailing at the level of biomolecules (genetic code) and at higher levels could be in question. This dynamics is dynamics for a society of conscious entities, which can decide whether to follow the rules or not. Rules as such do not matter too much: what is important that they make possible to predict the behavior of individuals and therefore make possible co-operation and formation of coherent and synchronous large scale structures making possible collective consciousness. In human society moral rules, laws, traffic rules, grammatical rules of language, etc... are examples about symbolic dynamics having very little to do with the laws of physics at fundamental level.

A natural question is whether the rules for building quasicrystals could provide a simplified model for this "social" dynamics - or perhaps even semi-realistic description - at the molecular level? Either quasicrystals or their building bricks - the arguments to be discussed later suggest that finite-sized quasicrystals - could be seen as a kind of society. The refusal to obey the rules guaranteeing the formation of larger quasicrystals would stop the quasicrystal growth and isolate the individual quasicrystal from the society. It could also lead to metabolic starvation: metabolic energy feed is indeed crucial element in living systems.

Quasicrystals could be seen as idealized structures having maximal complexity and therefore ability to represent information. Critical systems - also quantum critical ones - have a universal dynamics so that there is a large number of models making the same predictions for a given system. In practice this can be used to find the simplest possible model to simplify the mathematical description (say by finding the simplest conformal field theory to describe a 2-D critical system). From this point of view quasicrystals could be seen as an especially simple model possibly able to catch the universal properties of a real world system.

Does this self-organization dynamics then emerge only at and above bio-molecular scales or in all scales?

1. In TGD framework the classical dynamics at the fundamental level would be the geometro-dynamics of space-time surfaces (see `http://tinyurl.com/ybp86sho`) [K27]. Quantum Dynamics would be dictated by Dirac equation for WCW ("world of classical worlds") spinor

fields and reduce to the modified Dirac equation (see http://tinyurl.com/y8ha6fuy) for second quantized induced spinor fields at space-time surfaces.

The fractality of the TGD Universe suggests that self-organization occurs in all length scales above CP_2 scale, which is about 10^4 times Planck scale. If so, structures analogous to finite pieces quasicrystals could appear in all scales down to CP_2 scale.

2. I have proposed a method for constructing preferred extremals of Kähler action [K34] and this recipe leads to an iteration procedure. Quite generally, iteration is known to lead to fractals as fixed sets of iteration. Therefore space-time surfaces could be seen as space-time correlates of self-organization patterns and fractals.

3. Fractality would mean that even inanimate matter should share some aspects assigned to living matter and that also systems like species and biosphere could behave like living organisms in some respects. Sheldrake is famous for his notion of memory at the level of entire species. He has also proposed that even inanimate systems could have "habits". For instance, minerals would have adopted the habit to crystallize to a particular crystal form. In this framework living matter would differ from mineral kingdom in that its habits would be much more flexible. I have discussed the implementation of Sheldrake's ideas in TGD framework (see http://tinyurl.com/y79kxbua) [L1].

7.3 Could Ordered Water Layers Around Biomolecules Be Modelled As Quasicrystal Like Structure?

Water forms multilayered quasi-lattices (to be distinguished from quasicrystals!). These quasi-lattices around molecules are like ice coverings. These quasilattices have water molecule as a basic tetrahedral building blocks giving rise to icosahedral blocks (as suggested in discussions): the 4 electron pairs of water molecule are indeed located at the vertices of tetrahedron and for lattice like structures a regular tetrahedron is in question. Perhaps these quasi-lattices could be modelled as deformed quasicrystals.

This molecular ice would form a quasicrystal, which could somehow store information about environment via its structural degeneracy. If the information is conscious, it should be stored in the negentropic entanglement between the states of finite-sized quasi-lattices surrounding two separate molecules, and would have magnetic flux sheets connecting them as a space-time correlate. For 3-D quasicrystal like structure the lattice points would be in the intersections of 3 2-planes (or thin locally planar flux sheets) and define points of a lattice at which the analogs of coordinate planes meet.

Making these structures dynamical one would obtain 4-D quasicrystal like structures. In this case the intersections of 2 3-planes (or thin locally planar 3-D flux sheets) would give rise to 1-dimensional word lines of 3-D quasicrystal points whereas the intersections of 3 3-planes would correspond to points of 4-D lattice. What special could happens at these dynamically special points of space-time?

Zero energy ontology and TGD inspired theory of consciousness allows to consider a possible answer: the points of 4-D lattice correspond to CDs (causal diamonds) serving as space-time correlates for sub-selves identifiable as mental images. Quite generally quasi-periodically appearing mental images might be assigned to the points of quasi-lattice like structure.

Note that also cubic crystals can be constructed using grid consisting now of 3 orthogonal planes and the distances between grid planes serve as geometrical parameters which magnetic body could vary. The constant deformation of the magnetic body would now however force rather large deformations of crystal structure probably impossible energetically. One can however ask whether phonons could be induced by the local deformations of the flux sheets of the grid inducing small oscillations of the lattice points. If the magnetic body indeed serves as the intentional agent using biological body, this connection might allow to understand the very special role of acoustic oscillations in hearing, speech, internal speech, and thought. For instance, could the reaction of magnetic flux sheets to sound give rise to hearing? And could the reaction of the quasilattice units to the oscillations of the flux sheets give rise to internal speech or induce even speech in sound organs? It has been argued that the structure of the intronic portion of DNA resembles that of language and this has led to proposal that acoustic waves propagating along DNA could code for

language. If DNA is indeed accompanied by flux tubes and flux sheets, this idea would look rather natural in the recent context.

One of the basic findings of biology is that protein molecules are most of the time in a resting state in a folded configuration with globular form and surrounded by ordered water defining kind of ice covering. This state could represent conscious information realized as a negentropic entanglement between different molecules: kind of a molecular meditative state would be in question. In the presence of energy feed inducing "molecular summer" the molecular ice would melt, globular proteins would open and self-organize to form molecular aggregates as a reaction to the energy feed. After the energy feed stops, molecules would fold back to the globular form but the memory from the "molecular summer" would be stored to the negentropic entanglement between molecules.

The Indra's net formed by the magnetic flux tubes and sheets has become a standard part of TGD based view about living matter. The model for "DNA as quantum computer" (see `http://tinyurl.com/ybyscdpt`) [K9] involves flux sheets traversing through DNA strand and flux tubes connecting nucleotides to lipids of the cell membrane as well as flux sheets with the shape of cell membrane. This suggests that one actually has also in the case of DNA-cell membrane system three orthogonal grids of flux sheets at some scale and flux tubes condensed at the sheets of grids. These structure would organized the living matter to a well-organized geometric structure.

One of the first really crazy ideas (see `http://tinyurl.com/yaf2pww3`) related to the magnetic was the proposal that the magnetic bodies associated with living organisms could have shape reflecting the shape of the organism and its parts - even in the length scale of Earth [K16]. If one takes the flux sheets grids seriously, and replaces planes with closed surfaces obtained by scaling outer surfaces for parts of the organism, something like this is indeed expected.

7.4 What Could Be The Variational Principle Behind Self-Organization?

Quasicrystals, say Penrose tilings (see `http://tinyurl.com/yc75bvd8`), have a huge ground state degeneracy: given region of quasicrystal can be completed to infinite number of quasicrystals. For crystals the situation is different: local empire is the entire infinite crystal. Quasicrystals are clearly analogous to spin glass systems also possessing also large ground state degeneracy.

TGD Universe is a 4-D spin glass, and this degeneracy would imply non-determinism analogous to the non-determinism of quasi-crystal dynamics in 4-D 4-D Minkowski space) with local empires interpreted as self-organization patterns and global empires reflecting the long range correlations due to intentional action and obedience for social rules. In human society the ability to predict what person probably does next year in given day only by knowing his profession, would represent example about this kind of long range correlation caused basically by social forces.

7.4.1 Why Negentropy Maximization Principle should favor quasicrystals?

In TGD inspired theory of consciousness Negentropy Maximization Principle (NMP) (see `http://tinyurl.com/yd3mly5m`) [K18] is the basic variational principle. NMP states that the information contents of conscious experience is maximal. Therefore entanglement negentropy is expected to be the fundamental quantity.

1. Since conscious entities forming larger coherent structures (societies) are in question, it seems that one should characterize the quasi-lattice by a negentropy, which should be maximized (purely mathematically negentropy is very similar to entropy which is maximized for a closed system). This negentropy would *not* correspond to the negative of the ordinary thermodynamical entropy, which characterizes ensemble of particles rather than single coherent unit.

2. In TGD Universe this negentropy would naturally be the number theoretic negentropy characterizing negentropic entanglement (see **Fig.** `http://tgdtheory.fi/appfigures/cat.jpg` or **Fig. ??** in the appendix of this book) identified as a measure for conscious information. This information measure is assigned with the magnetic flux tubes connecting biomolecules and other units of living organism and even living organisms to larger coherent structures. In the case of quasicrystals flux tubes or flux sheets give rise to the long range constraints binding the units of quasi-crystal to each other.

3. The maximization of negentropy characterizing information content of conscious experience should be equivalent with the maximization of complexity as the number of almost degenerate ground states of quasicrystal. It is intuitively clear why quasicrystals would be favored over crystals. But how quasicrystals could maximize entanglement negentropy? Why the entanglement negentropy would be large for quasicrystals? Why the large number of quasicrystals configurations would favor large entanglement negentropy.

   If the entanglement is between two different quasicrystals, it means formation of quantum superposition of pairs of quasicrystal configurations and the higher the quasicrystal degeneracy, the larger the maximal entanglement negentropy. This conforms with the fact that quasicrystals are necessary of finite size. Most naturally the negentropic entanglement would be between the degenerate ground states of two finite-sized quasicrystals.

4. If degrees of freedom associated with the space-time geometry are entangled, the quantum dynamics at the level of "world of classical worlds" would be involved and by definition would not be describable by QFT in a fixed background space-time. One could speak about genuine quantum gravity: The Orch-OR proposal of Penrose and Hameroff is also a conjecture of similar character. One can also consider entanglement between states of some particle and quasicrystal but the negentropy content would be now much smaller due to the small number of particle states.

7.4.2 Maximal capacity to represent information with minimal metabolic energy costs as a basic variational principle?

The interpretation as a symbolic dynamics assignable to conscious entities would suggest that the maximization of the capacity to represent information (perhaps with minimal metabolic costs) could be the variational principle behind this dynamics. The number of different quasicrystals formed using the given rules should be maximal. This would give rise to very large number of states with nearly same energy allowing to represent the states of the external world (primitive sensory system). The larger the size of quasicrystal, the larger the number of degenerate configurations. Here of course physical constraints would pose an upper limit of the size.

But can one really assume rigid rules of construction giving rise to only quasicrystals? If the basic dynamical units are conscious entities they refuse to obey strict rules although they can decide to do so under "social pressures" (absence of metabolic energy feed can transform a sinner a saint!). Should these rules be an outcome of the variational principle alone? Or are they forced by some minimization principle - say minimization of metabolic energy feed - in presence of quasi-periodic background field configuration regarded as an external field favoring quasicrystals?

It seems that all configurations of the basic units must be accepted a priori: in principle even random spatial configurations of the basic units. For random configurations complexity would be maximal but co-operation minimal, long range correlations would be absent, and the ability to represent information would be minimal. For crystals long range correlations and co-operation would be maximal but crystal would have minimal capacity to represent and mimic. The natural manner to achieve long range correlations is to assume slowly varying quasi-periodic fields configurations representing the "social forces". In TGD framework these fields would naturally correspond to magnetic flux quanta serving as basic building bricks of magnetic bodies controlling biological body.

Note that by previous argument, the capacity to store conscious information is equivalent with ability to generate negentropic entanglement.

7.4.3 A possible realization for 4-D dynamics favoring quasicrystal like structures

Can one imagine a physical realization of 4-D quasicrystal dynamics in TGD framework? The basic problem is to understand how the rules for the formation of quasicrystals are forced. Certainly the hyper-plane grids associated with the basic polytope defining the quasicrystal force the long range correlations. But how to realize these grids physically?

1. In TGD Universe magnetic body acts as an intentional agent using biological body as a motor organ and sensory receptor. This suggests that the plane grids parallel to the faces of - say - icosahedron in the case of 3-D quasicrystal could in TGD Universe be realized as

thin (and thus effectively 2-D) magnetic flux sheets forming the magnetic body around which the ordinary matter would self-organize to form a quasicrystal as a configuration sustainable by using minimum metabolic energy feed. These grids would be part of the magnetic body responsible for the "social forces".

Rather remarkably, quite recent findings strongly suggest that brain involves an orthogonal grid of curved planes.(see `http://tinyurl.com/876lmaw`) Maybe this grid correspond to a quasi-lattice associated with a cubic basic unit serving as a basic information processing unit. Exact cubic crystal does not guarantee the needed ground state degeneracy and the deviation from it could be crucial in guaranteeing large degeneracy of the basic structures.

2. Maybe the basic variational principle could be minimization of the metabolic energy feed in presence of fixed grid structure formed by flux sheets representing the slow dynamics to which the molecular dynamics would rapidly adapt. The intersections of the grid hyper-planes are good candidates for the equilibrium points and going outside them would require metabolic energy. The minimum of the magnetic energy $\mu \cdot B$ of magnetic dipole is reduced in the intersections of flux sheets if the effects of the magnetic fields sum up at the intersection. For the crossing of n orthogonal sheets there is an enhancement by $\sqrt{n}$ factor. The motor activities of the magnetic body itself would deform the quasicrystals: the flux sheets could be deformed and the distances between the flux sheets could also vary. This would lead to new quasicrystal configurations with high negentropic content.

   From the point of view of individual quasicrystal regarded as conscious entity fight for survival would be fighting for metabolic resources and fusion with a bigger quasicrystal could be one manner to guarantee the availability of metabolic energy.

3. Phason dynamics (see `http://tinyurl.com/ycb86kzc`) seems to allow both short range description in terms of permutations of basic units and long range hydrodynamical description. Two dynamics seem to be present: slow *resp.* fast dynamics in short *resp.* long scales. Maybe these paradoxical properties of phasons could be understood in this framework if the microscopic fast dynamics forced by the slow long length scale dynamics of flux sheets.

4. Also other than quasicrystal configurations would be possible but would require higher metabolic energy feed to preserve entanglement negentropy (amount of conscious information). In 4-D case one would have similar grids of thin and effectively 3-D magnetic flux sheets associated with the 3-D faces (maybe icosahedrons) of 4-D building brick of quasicrystals. Magnetic flux sheets would carry dark matter and give rise to negentropic entanglement between the units of the quasicrystal.

5. The negentropic entanglement between two different quasi-crystal like structures means quantum superposition of different space-time surfaces since the grids formed by the flux sheets would have different geometric parameters such as the distance between the flux sheets of the grid. Hence genuine quantum gravitational effects would be in question having no description in QFT framework and requiring description at the level of WCW .

7.4.4 Summary

The essential element of picture would be spin glass degeneracy giving a large number of ground states making possible highly negentropic entanglement between separate spin glasses. Quasicrystals are not the only manner to satisfy this condition and 4-D quasi-lattices for which grid could contain also more general 3-surfaces than hyperplanes, can be considered. Grids of thin 3-surfaces would represent the rules forcing the quasi-lattice like configurations through localization to the word lines defined by intersections of two 3-surfaces. TGD inspired quantum model for biology suggests concrete models for the grids of flux sheets involving also flux tubes topologically condensed on them as a manner to generate negentropic entanglement. Also fractal structures consisting of flux quanta inside flux quanta are highly suggestive.

The basic variational principle of quasicrystal dynamics (and its generalization to quasi-lattices) could be minimization of metabolic energy feed in presence of fixed configuration of the magnetic body obeying a relatively slow dynamics. The time scale of EEG is in the range.01-.1 seconds gives a first guess for the time scale of the dynamics of the magnetic body in scale of Earth. This

time scale is to be compared to the time scale of 10^{-10} seconds of conformational dynamics biomolecules. Quasi-crystallization - or more generally, formation quasi-lattices - would be due to the existence of grids of thin 3-sheets parallel to the basic units of the 3-faces of 4-D basic unit of quasicrystal.

To show that this picture makes or does not make sense, one should be able to estimate reliably the metabolic energy feed needed to preserve a given negentropic entanglement entropy for a given configuration of the basic units (say clusters of water molecules) and to show that it is minimized for quasicrystal configurations in presence of the grid structure formed by flux sheets. This is probably relatively easy since the first guess for the equilibrium configurations corresponds to the highly symmetric crossing lines of for two 3-planes. One might also try to demonstrate the presence of negentropic entanglement between molecules, which are in resting state. This would be a direct demonstration for the notion of WCW and for non-trivial quantum gravity effects in living matter.

7.5 Could Quasi-Lattices And Quasi-Crystals Emerge From The Notion Of P-Adic Manifold?

This section is inspired by the considerations of the new chapter "What p-adic icosahedron could mean? And what about p-adic manifold?" [K36]. The original purpose was to understand what the notion of p-adic icosahedron could mean but soon it turned out that the key challenge is to understand what p-adic manifold means. Also in TGD framework this is one of the basic challenges posed by the condition of number theoretical universality and the idea about algebraic continuation of physics between different number fields.

The basic problem is that p-adic topology is totally disconnected meaning that p-adic balls are either disjoint or nested so that the usual construction of manifold structure fails. The basic criticism against the notion of p-adic icosahedron, and more generally, the notion of p-adic manifold, is the technical complexity of the existing constructions by mathematicians.

TGD however suggests much simpler construction. The construction relies on a simple modification of the notion of manifold inspired by the interpretation of p-adic preferred extremals defining counterparts of real preferred extremals as cognitive representations of the latter. This requires a mapping from p-adic preferred extremals to real ones and vice versa. In manifold theory chart maps are the analogs of these maps and the only difference is that they are between different number fields.

What I have christened as canonical identification $I^Q_{k,l}$ mapping rationals $p^{rk}m/n$ with $|m|_p > p^{-k}$, $|n|_p > p^{-k}$, as $I^Q_{k,l}(p^{rk}(m/n)) = p^{-rk}I_{k,l}(m)/I_{k,l}(n)$, where $I_{k,l}(m = \sum m_n p^{nk}) = \sum_{n<l} m_n p^{-nk}$ defines canonical identification for p-adic numbers m, n satisfying the above conditions in their pinary expansion with two cutoffs k and l. $I^Q_{k,l}$ is ill defined for irrational p-adic numbers since for them the representation as rational is not unique. A generalization to algebraic extensions is straightforward.

$I^Q_{k,l}$ is a compromise between the direct identification along common rationals favored by algebra and symmetries but being totally discontinuous without the cutoff $n < l$. This cutoff breaks symmetries slightly but guarantees continuity in finite measurement resolution defined by the pinary cutoff l. Symmetry breaking can be made arbitrarily small and has interpretation in terms of finite measurement resolution. Due to the pinary cutoff the chart map applied to various p-adic coordinates takes discrete set of rationals to discrete set of rationals and preferred extremal property can be used to make a completion to a real space-time surface. Uniqueness is achieved only in finite measurement resolution and is indeed just what is needed. Also general coordinate invariance is broken in finite measurement resolution. In TGD framework it is however possible to find preferred coordinates in order to minimize this symmetry breaking.

7.5.1 TGD based view about p-adic manifolds

The construction of p-adic manifold topology somehow overcoming the difficulty posed by the fact that p-adic balls are either disjoint or nested is necessary. It should also allow a close relationship between p-adic and real preferred extremals. It will be found that TGD leads naturally to a proposal of p-adic manifold topology [K36] based on canonical identification used to map the predictions of p-adic mass calculations to real numbers. This map would define coordinate charts for p-adic space-time surfaces - not as p-adic chart leafs as in the standard approach - but as

real chart leafs. The real topology induced from real map leafs to the p-adic realm would be path-connected as required.

In TGD framework one must also require finite measurement resolution meaning that the canonical identification is characterized by pinary cutoff takes a discrete subset of rational points of p-adic preferred extremal to its real counterpart: for a subset of this subset rationals are mapped to themselves. One can complete this point set to a real preferred extremal in finite measurement resolution. This construction allows also to define p-adic integrals and differential forms in terms of their real counterparts by algebraic continuation. Therefore geometric notions like distance and volume make sense and there is a very close correspondence between real space-time geometries and their p-adic counterpart in the situations when they exist.

7.5.2 Can one consider a p-adic generalization of Penrose tiling and quasicrystals?

The mathematically rigorous generalization of Penrose Tilings and quasicrystals to p-adic context might be possible but is bound to be rather technical. The p-adic icosahedron as it is defined in the article does not seem very promising notion. The point is that it is defined in terms of fixed point set for subgroups of icosahedral group acting on Riemann sphere: the action in Euclidian 3-space is now more natural and certainly makes sense and actually simplifies the situation since Q_p^3 sd analog of E^3 is simplest possible 3-D p-adic manifold. It does not however allow Bruhat-Tits tree since the points of Q_p^n are not in 1-1 correspondence with the lattices of Q_p^n. The possibility to construct Bruhat-Tits tree is a special feature of projective spaces.

TGD based view about p-adic E^3 and S^2 as its sub-manifold allows to define also the counterpart of Penrose tiling and QCs in an elegant manner with a close relationship between real and p-adic variants of QC.

1. If one considers lattices in n-dimensional p-adic space Q_p^n replacing E^n, a more natural definition would be in terms of this space than in terms of sphere. For the counterpart of E^3 one can define the action of the subgroup A_5 of rotation group $SO(3)$ by introducing an algebraic extension of the p-adic numbers containing $cos(2\pi/5)$, $sin(2\pi/5)$ and $cos(2\pi/3)$, $sin(2\pi/3)$ and their products. What is interesting is that algebraic extension is forced automatically in p-adic context! In cut and project (see `http://tinyurl.com/ybdbvjoa`) method [A3] the QC structure requires also this since the imbedded space has an algebraic dimension over integers equal to the dimension of the imbedding space over reals.

   Could it be that p-adic variants of QCs might provide number theoretic insights about QCs? Subspace would define algebraic extension of p-adic numbers and this extension would be such that it allows the representation of the isometry group of the Platonic solid possibly assignable to the QC.

2. One can also now define the icosahedron or any Platonic solid in terms of fixed points also now. Only discrete subgroups of the rotation group can be represented p-adically since algebraic extension is required. This brings in mind the notion of finite measurement resolution leading to a discretization of p-adically representable rotations and more general symmetries. For instance, without algebraic extension only rotations for which the rotation matrices are rational numbers are representable. It seems that finite subgroups of this kind are generated by rotations with rotation angle $\pi/2$ around various coordinate axes. Pythagorean triangles correspond to rationals values of cosine and sine and rotations for which rotation angle corresponds to Pythagorean angle define rational rotation matrices: these groups are discrete but contain infinite number of elements.

   Altogether this suggests a hierarchy of p-adic extensions leading to higher algebraic dimensions and larger discrete symmetries. This conforms with the general number theoretic vision about TGD.

3. Lattices in Q_p^n with integer coefficients make also sense and are characterized by n linearly independent (over p-adic integers) basic vectors $(a_1, ..., a_n)$. Most points of lattice would correspond to values of p-adic integers n_i in $\sum_i n_i a_i$ infinite as real numbers.

   Consider first a non-realistic option in which p-adic integers are mapped to p-adic integers as such. Note also that most of p-adic lattice points would map to real infinity. This

kind of correspondence makes sense also for rationals but would give a totally discontinuous correspondence between reals and p-adics.

p-Adic manifold topology defined in terms of the canonical identification I_{kl} allows to interpret the p-adic lattice as a cognitive representation of the real one. The presence of pinary cutoffs k and l having interpretation in terms of finite cognitive resolution has two implications. Integers $n_i < p^k$ are mapped to themselves so that this portion of lattice is mapped to itself faithfully. The integers $k \leq n < l$ are not mapped to integers and the length of the image is bounded below. The real image of the p-adic lattice under I_{kl} is necessary compressed to a finite volume of E^3. This kind of compression and cutoff is natural for cognitive representations for which numerics with finite cutoff provides one particular analogy.

4. Could the notion of p-adic QC and Penrose tiling make sense if one considers p-adic counterparts of Euclidian space and a n-D cubic lattice with integer valued coefficients and spanned by unit vectors? Could the cut and project method (see `http://tinyurl.com/ybdbvjoa`) [A3] generalize?

   This is not clear since projection would lead from a lattice in Q_p^n to a QC in lower-dimensional space which is associated with algebraic extension of Q_p but having algebraic dimension equal to n. If this space is K^m, K an algebraic extension of Q_p, one has $n = dim(K) \times m$. For prime values of n this would mean that $m = 1$ and one has n-D algebraic extension.

   Projection should be generalized to a map mapping points of n-D space to m-dimensional subspace K^m associated with algebraic extension of Q_p. Maybe it is better to formally extend Q_p^n to K^n and restrict the lattice to integer lattice in $Q_p^n \subset K^n$. In this manner the projection becomes well-defined as map from $Q_p^n \subset K^n$ to a subspace K^m of K^n. The basic condition could be that the points of the subspace K^m in K^n with algebraic dimension $n \times dim(K)$ define and m-dimensional subspace over K and n-dimensional subspace of Z_p.

   The "irrational angles" associated with the lower-dimensional subspace defining quasilattice defining algebraic extension of Q_p should be such that it allows the representation of the isometry group of the p-adic Platonic solid possibly assignable to the QC in question.

7.5.3 Cut and project construction of quasicrystals from TGD point of view

Cut and projec (see `http://tinyurl.com/ybdbvjoa`) [A3] method is used to construct quasicrystals (QCs) in sub-spaces of a higher-dimensional linear space containing an ordinary space filling lattice, say cubic lattice. For instance, 2-D Penrose tiling is obtained as a projection of part of 5-D cubic lattice - known as Voronyi cell - around 2-D sub-space imbedded in five-dimensional space. The orientation of the 2-D sub-space must be chosen properly to get Penrose tiling. The nice feature of the construction is that it gives the entire 2-D QC. Using local matching rules the construction typically stops.

1. Sub-manifold gravity and generalization of cut and project method

The representation of space-time surfaces as sub-manifolds of 8-D $H = M^4 \times CP_2$ can be seen as a generalization of cut and project method.

1. The space-time surface is not anymore a linear 4-D sub-space as it would be in cut and project method but becomes curved and can have arbitrary topology. The imbedding space ceases to be linear $M^8 = M^4 \times E^4$ since E^4 is compactified to CP_2. Space-time surface is not a lattice but continuum.

2. The induction procedure geometrizing metric and gauge fields is nothing but projection for H metric and spinor connection at the continuum limit. Killing vectors for CP_2 isometries can be identified as classical gluon fields (see **Fig. 4**). The projections of the gamma matrices of H define induced gamma matrices at space-time surface. The spinors of H contain additional components allowing interpretation in terms of electroweak spin and hyper-charge.

2. Finite measurement resolution and construction of p-adic counterparts of preferred extremals forces "cut and project" via discretization

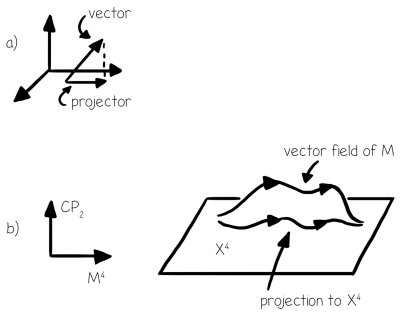

Figure 4: Induction of spinor connection and metric as projection to the space-time surface

In finite measurement resolution realized as discretization by finite pinary cutoff one can expect to obtain the analog of cut and project since 8-D imbedding space is replaced with a lattice structure.

1. The p-adic/real manifold structure for space-time is induced from that for H so that the construction of p-adic manifold reduces to that for H.

2. The definition of the manifold structure for H in number theoretically universal manner requires for H discretization in terms of rational points in some finite region of M^4. Pinary cutoffs- two of them - imply that the manifold structures are parametrized by these cutoffs charactering measurement resolution. Second cutoff means that the lattice structure is piece of an infinite lattice. First cutoff means that only part of this piece is a direct imagine of real/p-adic lattice on p-adic/real side obtained by identifying common rationals (now integers) of real and p-adic number fields. The mapping of this kind lattice from real/p-adic side to p-adic/real side defines the discrete coordinate chart and the completion of this discrete structure to a preferred extremal gives a smooth space-time surface also in p-adic side if it is known on real side (and vice versa).

3. Cubic lattice structures with integer points are of course the simplest ones for the purposes of discretization and the most natural choice for M^4. For CP_2 the lattice is completely analogous to the finite lattices at sphere defined by orbits of discrete subgroups of rotation group and the analogs of Platonic solids emerge. Probably some mathematician has listed the Platonic solids in CP_2.

4. The important point is that this lattice like structure is defined at the level of the 8-D imbedding space rather than in space-time and the lattice structure at space-time level contains those points of the 8-D lattice like structure, which belong to the space-time surface. Finite measurement resolution suggests that all points of lattice, whose distance from space-time surface is below the measurement resolution for distance are projected to the space-time surface. Since space-time surface is curved, the lattice like structure at space-time level obtained by projection is more general than QC.

The lattice like structure results as a manifestation of finite measurement resolution both at real and p-adic sides and can be formally interpreted in terms of a generalization of cut and project but for a curved space-time surface rather than 4-D linear space, and for H rather than 8-D Minkowski space. It is of course far from clear whether one can obtain anything looking like say 3-D or 4-D version of Penrose tiling.

1. The size scale of CP_2 is so small (10^4 Planck lengths) that space-time surfaces with 4-D M^4 projection look like M^4 in an excellent first approximation and using M^4 coordinates the projected lattice looks like cubic lattice in M^4 except that the distances between points are

not quite the M^4 distances but scaled by an amount determined by the difference between induced metric and M^4 metric. The effect is however very small if one believes on the general relativistic intuition.

In TGD framework one however can have so called warped imbeddings of M^4 for which the component of the induced metric in some direction is scaled but curvature tensor and thus gravitational field vanishes. In time direction this scaling would imply anomalous time dilation in absence of gravitational fields. This would however cause only a the compression or expansion of M^4 lattice in some direction.

2. For Euclidian regions of space-time surface having interpretation as lines of generalized Feynman diagrams M^4 projection is 3-dimensional and at elementary particle level the scale associated with M^4 degrees of freedom is roughly the same as CP_2 scale. If CP_2 coordinates are used (very natural) one obtains deformation of a finite lattice-like structure in CP_2 analogous to a deformation of Platonic solid regarded as point set at sphere. Whether this lattice like structure could be seen as a subset of infinite lattice is not clear.

3. One can consider also string like objects $X^2 \times Y^2 \subset M^4 \times CP_2$ with 2-D M^4 projection and their deformations. In this case the projection of M^4 lattice to X^2 - having subset of two M^4 coordinates as coordinates - can differ considerably from a regular lattice since X^2 can be locally tilted with respect to M^4 lattice. This cannot however give rise to Penrose tiling requiring 5-D flat imbedding space. This argument applies also to 2-D string world sheets carrying spinor modes. In the idealized situation that string world sheet is plane in M^4 one might obtain an analog of Penrose tiling but with 4-D imbedding space.

The above quasi lattice like structures (QLs) are defined by a gravitational deformation of the cubic lattice of M^4. Is there any hope about the 4-D QLs in M^4 so that gravitation would give rise to the analogs of phason waves deforming them? Could cut and project method be generalized to give QL in M^4 as projection of 8-D cubic lattice in M^8?

3. $M^8 - H$ duality

Before considering an explicit proposal I try to describe what I call $M^8 - H$ duality ($H = M^4 \times CP_2$).

1. What I have christened $M^8 - H$ duality is a conjecture stating that TGD can be equivalently defined in M^8 or $M^4 \times CP_2$. This is the number theoretic counterpart of spontaneous compactification of string models but has nothing to do with dynamics: only two equivalent representations of dynamics would be in question.

2. Space-time surfaces (preferred extremals) in M^8 are postulated to be quaternionic submanifolds of M^8 possessing a fixed $M^2 \subset M^4 \subset M^8$ as sub-space of tangent space. "Quaternionic" means that the tangent space of M^4 is quaternionic and thus associative. Associativity conditions would thus determine classical dynamics. More generally, these subspaces $M^2 \subset M^8$ can form integrable distribution and they define tangent spaces of a 2-D submanifold of M^4. If this duality really holds true, space-time surfaces would define a lattice like structure projected from a cubic M^8 lattice. This of course does not guarantee anything: $M^8 - H$ duality itself suggests that these lattice like structures differ from regular M^4 crystals only by small gravitational effects.

3. The crucial point is that quaternionic sub-spaces are parametrized by CP_2. Quaternionic 4-surfaces of $M^8 = M^4 \times CP_2$ containing the fixed $M^2 \subset M^8$ can be mapped to those of $M^4 \times CP_2$ by defining M^4 coordinates as projections to preferred $M^4 \subset M^8$ and CP_2 coordinates as those specifying the tangent space of 4-surface at given point.

4. A second crucial point is that the preferred subspace $M^4 \subset M^8$ can be chosen in very many manners. This imbedding is a complete analog of the imbedding of lower-D subspace to higher-D one in cut and project method. M^4 can be identified as any 4-D subspace imbedded in M^4 and the group $SO(1,7)$ of 8-D Lorentz transformations defines different imbeddings of M^4 to M^8. The moduli space of different imbeddings of M^4 is the Grassmannian $SO(1,7)/SO(1,3) \times SO(4)$ and has dimension $D = 28 - 6 - 6 = 16$.

When one fixes two coordinate axes as the real and one imaginary direction (physical interpretation is as an identification of rest system and spin quantization axes), one obtains $SO(1,7)/SO(2) \times SO(4)$ with higher dimension $D = 28 - 1 - 6 = 21$. When one requires also quaternionic structure one obtains the space $SO(1,7)/SU(1) \times SU(2)$ with dimension $D = 28 - 4 = 24$. Amusingly, this happens to be the number of physical degrees of freedom in bosonic string model.

4. How to obtain quasilattices and quasi-crystals in M^4?

Can one obtain quasi-lattice like structures (QLs) at space-time level in this framework? Consider first the space-time QLs possibly associated with the standard cubic lattice L^4_{st} of M^4 resulting as projections of the cubic lattice structure L^8_{st} of M^8.

1. Suppose that one fixes a cubic crystal lattice in M^8, call it L^8_{st}. Standard M^4 cubic lattice L^4_{st} is obtained as a projection to some M^4 sub-space of M^8 by simply putting 4 Euclidian coordinates for lattice points o constant. These sub-spaces are analogous to 2-D coordinate planes of E^3 in fixed Cartesian coordinates. There are $7!/3!4! = 35$ choices of this kind.

   One can consider also E_8 lattice (see `http://tinyurl.com/y9x7vevr`) is an interesting identification for the lattice of M^8 since E_8 is self-dual and defines the root lattice of the exceptional group E_8. E_8 is union of Z^8 and $(Z + 1/2)^8$ with the condition that the sum of all coordinates is an even integer. Therefore all lattice coordinates are either integers or half-integers. E_8 is a sub-lattice of 8-D cubic lattice with 8 generating vectors $e_i/2$, with e_i unit vector. Integral octonions are obtained from E_8 by scaling with factor 2. For this option one can imbed L^4_{st} as a sub-lattice to Z^8 or $(Z + 1/2)^8$.

2. Although $SO(1,3)$ leaves the imbedded 4-plane M^4 invariant, it transforms the 4-D crystal lattice non-trivially so that all 4-D Lorentz transforms are obtained and define different discretizations of M^4. These are however cubic lattices in the Lorentz transformed M^4 coordinates so that this brings nothing new. The QLs at space-time surface should be obtained as gravitational deformations of cubic lattice in M^4.

3. L^4_{st} indeed defines 4-D lattice at space-time surface apart from small gravitational effects in Minkowskian space-time regions. Elementary particles are identified in TGD a Euclidian space-time regions - deformed CP_2 type vacuum extremals. Also black-hole interiors are replaced with Euclidian regions: black-hole is like a line of a generalized Feynman diagram, elementary particle in some sense in the size scale of the black-hole. More generally, all physical objects, even in everyday scales, could possess a space-time sheet with Euclidian metric signature characterizing their size (AdS^5/CFT correspondence could inspire this idea). At these Euclidian space-time sheets gravitational fields are strong since even the signature of the induced metric is changed at their light-like boundary. Could it be that in this kind of situation lattice like structures, even QCs, could be formed purely gravitationally? Probably not: an interpretation as lattice vibrations for these deformations would be more natural.

It seems that QLs are needed *already at the level of* M^4. $M^8 - H$ duality indeed provides a natural manner to obtain them.

1. The point is that the projections of L^8_{str} to sub-spaces M^4 defined as the $SO(1,7)$ Lorentz transforms of L^4_{st} define generalized QLs parametrized by 16-D moduli space $SO(1,7)/SO(1,3) \times SO(4)$. These QLs include also QCs. Presumably QC is a QL possessing a non-trivial point group just like Penrose tiling has the isometry group of dodecagon as point group and 3-D analog of Penrose tiling has the isometries of icosahedron as point group.

   This would allow to conclude that the discretization at the level of M^8 required by the definition of p-adic variants of preferred extremals as cognitive representations of their real counterparts would make possible 4-D QCs. M^8 formulation of TGD would explain naturally the QL lattices as discretizations forced by finite measurement resolution and cognitive resolution.

   A strong number theoretical constraint on these discretizations come from the condition that the 4-D lattice like structure corresponds to an algebraic extension of rationals. Even more, if

this algebraic extension is 8-D (perhaps un-necessarily strong condition), there are extremely strong constraints on the 22-parameters of the imbedding. Note that in p-adic context the algebraic extension dictates the maximal isometry group identified as subgroup of $SO(1,7)$ assignable to the imbedding as the discussion of p-adic icosahedron demonstrates.

2. What about the physical interpretation of these QLs/QCs? As such QLs define only natural discretizations rather than physical lattices. It is of course quite possible to have also physical QLs/QCs such that the points - rather time like edge paths - of the discretization contain real particles. What about a "particle" localized to a point of 4-D lattice? In positive energy ontology there is no obvious answer to the question. In zero energy ontology the lattice point could correspond to a small causal diamond containing a zero energy state. In QFT context one would speak of quantum fluctuation. In p-adic context it would correspond to "though bubble" lasting for a finite time.

3. It is also possible to identify physical particles as edge paths of the 4-D QC, and one can consider time= constant snapshots as candidates for 3-D QCs. It is quite conceivable that the non-trivial point group of QCs favors them as physical QLs.

5. Expanding hyperbolic tesselations and quasi-tesselations obtained by imbedding $H^3 \subset M^4$ to $H^7 \subset M^8$

M^8-$M^4 \times CP_2$ duality and the discretization required by the notion of p-adic manifold relates in an interesting manner to expanding hyperbolic tesselations and quasi tesselations in $H^7 \subset M^8$, and possible expanding quasi-tesselations in obtained by imbedding $H^3 \subset M^4$ to $H^7 \subset M^8$

1. Euclidian lattices E_8, E_7, E_6

   I have already considered E_8 lattice in M^8. The background space has however Minkowskian rather than Euclidian metric natural for the carrier space of the E_8 lattice. If one assigns some discrete subgroup of isometries to it, it is naturally subgroup of $SO(8)$ rather than $SO(1,7)$. Both these groups have $SO(7)$ as a subgroup meaning that preferred time direction is chosen as that associated with the real unit and considers a lattice formed from imaginary octonions.

   E_8 lattice scaled up by a factor 2 to integer lattice allows octonionic integer multiplication besides sums of points so that the automorphism group of octonions: discrete subgroups of $G_2 \subset SO(7)$ would be the natural candidates for point groups crystals or lattice like structures.

   If one assumes also fixed spatial direction identified as a preferred imaginary unit, G_2 reduces to $SU(3) \subset SO(6) = SU(4)$ identifiable physically as color group in TGD framework. From this one ends up with the idea about $M^8 - M^4 \times CP_2$ duality. Different imbeddings of $M^4 \subset M^8$ are quaternionic sub-spaces containing fixed M^2 are labelled by points of CP_2.

   All this suggests that E_7 lattice in time=constant section of even E^6 lattice is a more natural object lattice to consider. Kind of symmetry breaking scenario $E_8 \to E_7 \to E_6 \to G_2 \to SU(3)$ is suggestive. This Euclidian lattice would be completely anomalous to a slicing of 4-D space-time by 3-D lattices labelled by the value of time coordinate and is of course just what physical considerations suggest.

2. Hyperbolic tesselations

   Besides crystals defined by a cubic lattice or associated with E_6 or E_7, one obtains an infinite number of hyperbolic tesselations in the case of M^8. These are much more natural in Minkowskian signature and could be also cosmologically very interesting. Quite generally, one can say that hyperbolic space is ideal for space-filling packings defined by hyperbolic manifolds H^n/Γ: they are completely analogous to space-filling packings of E^3 defined by discrete subgroups of translation group producing packings of E^3 by rhombohedra. One only replaces discrete translations with discrete Lorentz transformations. This is what makes these highly interesting from the point of view of quantum gravity.

   (a) In M^{n+1} one has tesselations of n-dimensional hyperboloid H^n defined by $t^2 - x1^2 - ... - x_n^2 = a^2 > 0$, where a defines Lorentz invariant which for $n = 4$ has interpretation

as cosmic time in TGD framework. Any discrete subgroup Γ of the Lorentz group $SO(1,n)$ of M^{n+1} with suitable additional conditions (finite number of generators at least) allows a tesselation of H^n by basic unit H^n/Γ. These tesselations come as 1-parameter families labelled by the cosmic time parameter a. These 3-D tesselations participate cosmic expansion. Of course, also ordinary crystals are crystals only in spatial directions. One can of course discretize the values of a or some function of a in integer multiples of basic unit and assign to each copy of H^n/Γ a "center point" to obtain discretization of M^{n+1} needed for p-adicization.

(b) For $n = 3$ one has M^4 and H^3, and this is very relevant in TGD cosmology. The parameter a defines a Lorentz invariant cosmic time for the imbeddings of Robertson-Walker cosmologies to $M^4 \times CP_2$. The tesselations realized as physical lattices would have natural interpretation as expanding 3-D lattice like structures in cosmic scales. What is new is that discrete translations are replaced by discrete Lorentz boosts, which correspond to discrete velocities and observationally to discrete red shifts for distant objects. Interestingly, it has been found that red shift is quantized along straight lines [**?**]: "God's fingers" is the term used. I proposed for roughly two decades ago an explanation based on closed orbits of photons around cosmic strings [K7]. but explanation in terms of tesselations would also give rise to periodicity. A fascinating possibility is that these tesselation have defined macroscopically quantum coherent structures during the very early cosmology the size scale of H^3/Γ was very small. One can also ask whether the macroscopic quantum coherence could still be there.

Hyperbolic manifold property has purely local signatures such as angle surplus: the very fact that there are infinite number of hyperbolic tesselations is in conflict with the fact that we have Euclidian 3-geometry in every day length scales. In fact, for critical cosmologies, which allow a one-parameter family of imbeddings to $M^4 \times CP_2$ (parameter characterizes the duration of the cosmology) one obtains flat 3-space in cosmological scales. Also overcritical cosmologies for which $a = constant$ section is 3-sphere are possible but only with a finite duration. Many-sheeted space-time picture also leads to the view that astrophysical objects co-move but do not co-expand so that the geometry of time=constant snapshot is Euclidian in a good approximation.

3. Does the notion of hyperbolic quasi-tesselation make sense?

   Can one construct something deserving to be called quasi tesselations (QTs)? For QCs translational invariance is broken but in some sense very weakly: given lattice point has still an infinite number of translated copies. In the recent case translations are replaced by Lorentz transformations and discrete Lorentz invariance should be broken in similar weak manner.

   If cut and project generalizes, QTs would be obtained using suitably chosen non-standard imbedding $M^4 \subset M^8$. Depending on what one wants to assume, M^4 is now image of M^4_{st} by an element of $SO(1,7)$, $SO(7), SO(6)$ or G_2. The projection - call it P - must take place to M^4 sliced by scaled copies of H^3 from M^8_{st} sliced by scaled copies of H^7/Γ tesselation. The natural option is that P is directly from H^7 to $H^3 \subset H^7$ and is defined by a projecting along geodesic lines orthogonal to H^3. One can choose always the coordinates of M^4 and M^8 in such a manner that the coordinates of points of M^4 are $(t,x,y,z,0,0,0,0)$ with $t^2 - r^2 = a_4^2$ whereas for a general point of H^7 the coordinates are $(t,x,y,z,x_4,...x_7)$ with $t^2 - r^2 - r_4^2 = a_8^2$ for $H^3 \subset H^7$. The projection is in this case simply $(t,x,y,z,x_4,...,x_7) \to (t,x,y,z,0,...,0)$. The projection is non-empty only if one has $a_4^2 - a_8^2 \geq 0$ and the 3-sphere S^3 with radius $r_4 = \sqrt{a_4^2 - a_8^2}$ is projected to single point. The images of points from different copies of H^7/Γ are identical if S^3 intersects both copies. For r_4 much larger than the size of the projection $P(H^7/\Gamma)$ of single copy overlaps certainly occurs. This brings strongly in mind the overlaps of the dodecagons of Penrose tiling and icosahedrons of 3-D icosahedral QC. The point group of tesselation would be Γ.

4. Does one obtain ordinary H^3 tesselations as limits of quasi tesselations?

   Could one construct expanding 3-D hyperbolic tesselations H_3/Γ_3 from expanding 7-D hyperbolic tesselations having H^7/Γ_7 as a basic building brick? This seems indeed to be the

outcome at at the limit $r_4 \to 0$. The only projected points are the points of H^3 itself in this case. The counterpart of the group $\Gamma_7 \subset SO(1,7)$ is the group obtained as the intersection $\Gamma_3 = \Gamma_7 \cap SO(1,3)$: this tells that the allowed discrete symmetries do not lead out from H^3. This seems to mean that the 3-D hyperbolic manifold is H^3/Γ_3, and one obtains a space-filling 3-tesselation in complete analogy for what one obtains by projecting cubic lattice of E^7 to E^3 imbedded in standard manner. Note that $\Gamma_3 = \Gamma_7 \cap SO(1,3)$, where $SO(1,3) \subset SO(1,7)$, depends on imbedding so that one obtains an infinite family of tesselations also from different imbeddings parametrized by the coset space $SO(1,7)/SO(1,3)$. Note that if Γ_3 contains only unit element $H^3 \subset H^7/\Gamma_7$ holds true and tesselation trivializes.

7.5.4 Do Penrose tilings correspond to edge paths of Bruhat-Tits tree for projective sphere $P^1(Q_p)$?

Perhaps it deservers to be mentioned that there is an amusing co-incidence with Penrose tilings (see the book "In search of the Riemann zeros" [A6] by Lapidus, page 200) and between the representation of 2-adic numbers. This representation is in terms of a a tree containing only 3-vertices. Incoming edge represents n: th binary digit in the expansions $x = \sum x_n 2^n$, $x_n = 0, 1$ and the two outgoing edges corresponds to the two values of the $n+1$: th binary digit. Each 2-adic number corresponds to a one particular edge path in this semi-infinite tree. This structure is very much analogous to Bruhat-Tits tree for p-adic projective line $P^1(Q_p)$ [A2] discussed in [K36].

A given Penrose tiling corresponds to semi-infinite bit string having only non-negative pinary digits and could be seen as a 2-adic integer. Two bit sequences describe same tiling if they differ from each other for a finite number bits only. Could the ends for the analog of Bruhat-Tits tree for p-adic integers (half-infinite paths beginning from some bit) be in one-one correspondence with Penrose tilings! Could one really describe 2-D Penrose tilings 2-adically? What about more general Penrose tilings and QCs? Maybe this conjecture is trivially true since Lapidus, who mentions this description of Penrose tilings, has written his book about p-adic strings [A6].

Unfortunately, I do not understand the arguments leading to the representation of Penrose tilings using bit sequences and whether this co-incidence has some deeper meaning.

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