Zero Energy Ontology

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Contents

Abstract

Zero energy ontology (ZEO) has become gradually one of the corner stones of quantum TGD. This motivates the collection of material related to ZEO in a single chapter providing an overall view about the development of ideas. The sections are independent and reflect different views about ZEO.

The following gives a brief summary of the most recent view (2021) of ZEO.

1. The notion of a causal diamond (CD) is a central concept. Its little cousin "cd" can be identified as a union of two half-cones of M^4 glued together along their bottoms (3-D balls). The half-cones are mirror images of each other. CD=$cd \times CP_2$ is the Cartesian product of cd with CP_2 and obtained by replacing the points of cd with CP_2. The notion of CD emerges naturally in the number theoretic vision of TGD (adelic physics via the $M^8 - H$ duality.
2. In ZEO, quantum states are not 3-dimensional if the determinism does not fail as it actually does, but superpositions of 4-dimensional deterministic time evolutions connecting ordinary 3-dimensional states. For the strongest form of holography implied by general coordinate invariance (GCI), the time evolutions are equivalent to pairs of ordinary 3-D states identified as initial and final states of time evolution.

   The failure of determinism probably implies that a given 3-surface at the passive boundary of CD (PB) corresponds to a finite number of 4-D minimal surfaces and that the minimal surface can be regarded as an analog of soap film spanned by a frame having fixed parts at the boundaries of CD and dynamically generated parts in the interior of CD. The frame can be identified as a topological analog of a Feynman diagram.
3. Quantum jumps replace this state with a new one: a superposition of deterministic time evolutions is replaced by a new superposition. The classical determinism of individual time evolution is not violated. This solves the basic paradox of quantum measurement theory. There are two kinds of SFRs: BSFRs (counterparts of ordinary SFRs) changing the arrow of time (AT) and SSFRs (analogs of "weak" measurements) preserving the arrow of time that give rise to an analog of the Zeno effect. The findings of Minev et al provide strong support for ZEO.

1 Introduction

Zero energy ontology (ZEO) has become gradually one of the corner stones of quantum TGD. This motivates the collection of material related to ZEO in a single chapter providing an overall view about the development of ideas. The sections are independent and reflect different views about ZEO.

1.1 ZEO in its recent form (2021)

The following gives a brief summary of the most recent view (2021) of ZEO [L35].

1. The notion of a causal diamond (CD) (see **Fig. ??**) is a central concept. Its little cousin "cd" can be identified as a union of two half-cones of M^4 glued together along their bottoms (3-D balls). The half-cones are mirror images of each other. CD=$cd \times CP_2$ is the Cartesian product of cd with CP_2 and obtained by replacing the points of cd with CP_2. The notion of CD emerges naturally in the number theoretic vision of TGD (adelic physics [L16])via the $M^8 - H$ duality [L30, L41, L42].

2. In ZEO, quantum states are not 3-dimensional if the determinism does not fail as it actually does, but superpositions of 4-dimensional deterministic time evolutions connecting ordinary 3-dimensional states. For the strongest form of holography implied by general coordinate invariance (GCI), the time evolutions are equivalent to pairs of ordinary 3-D states identified as initial and final states of time evolution.

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1.2 Topics of the chapter

The goal is to provide some conceptual background for the attempts to identify scattering amplitudes in the framework provided by ZEO.

In the section "*Zero Energy Ontology in its original form*" the basic ideas and implications of ZEO are described. I will represent motivations for ZEO in TGD framework, compare ZEO with the ordinary positive energy ontology, and try to make clear the implications of ZEO for quantum measurement theory since they relate also directly to the notion of conscious observer as it is understood in TGD inspired theory of consciousness.

In the section "*Some comments related to Zero Energy Ontology*" the basic ideas and notions of ZEO in its original form are critically discussed and also TGD based theory of consciousness is formulated in this framework.

In the section "*Still about quantum measurement theory in ZEO*" quantum measurement theory in ZEO framework is considered with a particular emphasis on number theoretic universality brought in by number theoretic aspects of TGD [L17, L16].

In the section "*Some questions concerning zero energy ontology*" the most recent(2021) view about ZEO is developed by making making objections against the the earlier view [L17, L16]. This view provides a formulation of ZEO at the level of "world of classical worlds" (WCW) and provides surprisingly insights to quantum TGD and TGD inspired theory of consciousness.

For a fixed 3-surface at PB, quantum non-determinism corresponds to a discrete classical non-determinism due to the failure of a strict determinism. The classical orbits of the 3-surface form a tree and zero energy states are superpositions of paths of this tree. Interestingly, this notion of non-determinism is equivalent with the notion of association sequence that I introduced in the early developmental phases of TGD inspired theory of consciousness.

2 Zero Energy Ontology in its original form

Zero energy ontology has changed profoundly the views about the construction of S-matrix and forced to introduce the separate notions of M-matrix and U-matrix. M-matrix generalizes the notion of S-matrix as used in particle physics. The unitary U-matrix is something new having a natural place in TGD inspired theory of consciousness. Therefore it it best to begin the discussion with a brief summary of zero energy ontology.

2.1 Motivations For Zero Energy Ontology

Zero energy ontology was first forced by the finding that the embeddings of Robertson-Walker cosmologies to $M^4 \times CP_2$ are vacuum extremals. The interpretation is that positive and negative energy parts of states compensate each other so that all quantum states have vanishing net quantum numbers. One can however assign to state quantum numbers as those of the positive energy part of the state. At space-time level zero energy state can be visualized as having positive energy part in geometric past and negative energy part in geometric future. In time scales shorter than the temporal distance between states positive energy ontology works. In longer time scales the state is analogous to a quantum fluctuation.

Zero energy ontology gives rise to a profound distinction between TGD and standard QFT. Physical states are identified as states with vanishing net quantum numbers, in particular energy. Everything is creatable from vacuum - and one could add- by intentional action so that zero energy ontology is profoundly Eastern. Positive *resp.* negative energy parts of states can be identified as states associated with 2-D partonic surfaces at the boundaries of future *resp.* past directed

light-cones, whose tips correspond to the arguments of n-point functions. Each incoming/outgoing particle would define a mini-cosmology corresponding to not so big bang/crunch. If the time scale of perception is much shorter than time interval between positive and zero energy states, the ontology looks like the Western positive energy ontology. Bras and kets correspond naturally to the positive and negative energy states and phase conjugation for laser photons making them indeed something which seems to travel in opposite time direction is counterpart for bra-ket duality.

2.2 Zero Energy Ontology

Zero energy ontology (ZEO) is one of the cornerstones of TGD and has become part of TGD during last six years. Zero energy states are identified as superpositions of pairs of positive and negative energy states assigned with the future and past boundaries of causal diamonds (CDs) and correspond in ordinary ontology to physical events with positive and negative energy parts of the state identified as counterparts for the initial and final states of the event. Effective 2-dimensionality allows a further reduction to the level of partonic 2-surfaces: also their 4-D tangent space data matter. Symmetry considerations lead to a beautiful view about generalizations S-matrix to U-matrix in terms o forthogonal M-matrices which in turn are expressible as products of orthogonal basis of hermitian square roots of density matrices and unitary S-matrix [K18]. One can say that quantum theory is "complex" square root of thermodynamics.

Therefore one should try to find tests for ZEO.

2.2.1 The hierarchy of CDs

The basic assumption is that the sizes of CDs come as integer multiples of CP_2 scale R and for prime multiples of R correspond to secondary p-adic length scales $L_{p,2} = L_{p,1}\sqrt{p}$, $L_{p_1} = R\sqrt{p}$, where R denotes CP_2 scale. For electron with $p = M_{127} = 2^{127} - 1$ one has $T_{p_2} = .1$ seconds and defines a fundamental bio-rhythm. This time scale should have preferred role in physics. More generally the secondary p-adic time scales assignable to elementary particles should define time scales relevant to macroscopic physics. The corresponding size scale can be assigned to the magnetic body of the elementary particle. Also it should be possible to assign to quark mass scales special biological time scales as has been indeed done [K4]. h predictions could be tested.

2.2.2 Generalization of standard conservation laws in ZEO

ZEO together with sub-manifold geometry provides a new view about conservation laws and resolves the problem posed by the fact that gravitational interactions do not seem to respect energy conservation in cosmological time scales. Conservation laws holds true only in the scale associated with given CD, not universally (this would allow only single infinitely large CD).

Superconducting coherent states involve quantum superposition of states with different numbers of Cooper pairs and therefore break the super-selection rule associated with fermion number in ordinary ontology. In ZEO they could be understood without giving up the superselection rule associated with fermion number.

Experimental tests should try to prove that quantum number conservation is a length scale dependent notion. For instance, creation of matter from vacuum is possible in ZEO, and one might hope that its occurrenece could be in some scale for CDs aritficially.

2.2.3 Breaking of second law in standard form

In standard physics second law states that all systems are entropic but a system can reduce its entropy by feeding its entropy to the environment. Negentropic entanglement carries genuine information and life can be seen as islands of negentropy in the sea of entropy. This forces to generalized second law. The proposed generalization (see `http://tinyurl.com/ybg8qypx`) [L1] [K17] can be characterized as maximally pessimistic.

The generation of negentropic entanglement is assumed to be accompanied by generation of compensating entropic entanglement. The modified form of second law is suggested by the mechanism of directed attention based on negentropic entanglement assignable to magnetic flux tube connecting selfandtarget. Negentropic entanglement prevails during the attention but disappears

after state function reduction giving rise to entropy at the level of ensemble. Second law would hold true above time scale assignab le to the duration of negentropic entanglement.

There are also other reasons to reconsider second law. The breaking of second law in standard form since the arrow of geometric time can change locally. Living systems are indeed accompanied by syntropic effects as realized by Italian quantum physicist Fantappie [J2, J3]. These effects could be understood as entropic effects but with a reversed arrow of geometric time. The mechanism would be based on negative energy signals. Phase conjugate laser waves are known to obey second law in reversed direction of geometric time. Cooling effects due to the absorption of negative energy signals inducing the breaking of the standard form of the second law are predicted to be possible. One can also imagine a spontaneous excitation of atoms generating radiation in the return to ground state in a situation when there is a target able to receive negative energy signals emitted in spontaneous excitation.

Standard form of second law assumes that quantum coherence is absent in the scales in which it is applied. Both the hierarchy of Planck constants and negentropic entanglement however make possible macroscopic quantum coherence characterized by the scale involved and the natural guess is that the time scale associated with causal diamond in question defines the scale above which one can expect second law to hold. There is evidence for the breaking of second law in time scale of.1 seconds [D1].

2.2.4 Negative energy signals

Zero energy ontology allows to assign to zero energy states an arrow of time naturally since one can require that states have well defined single particle quantum numbers at either upper or lower boundary of CD. Also the spontaneous change of the arrow of geometric time is possible. The simplest possible description for U-process is that U-matrix relates to each other these two kinds of states and state function reductions can occur at upper and lower boundaries of CD meaning reduction to single particle states with well defined quantum numbers. The precise correlates for the generation of geometric arrow of time are not completely understood.

Negative energy signals to geometric past would serve as counterparts for time reversed states in the case of radiation and phase conjugate laser waves are natural counterparts for them. The signal property requires a dissipative process proceeding in preferred time direction and this kind of process has been assigned to sub-CDs and should proceed as state function reduction sequence in preferred direction of time determined by the quantum arrow of time for the zero energy state. This process would be essential for the experience of flow of time in preferred direction and for generation of arrow of geometric time as explain in previous chapter and also in [K2]. For phase conjugate laser beams the reversed time direction for dissipation is observed.

Negative energy signals make possible remote metabolism as sucking of energy from remote energy source provided resonance conditions for transitions are satisfied. The counterpart of population inverted laser could serve as ideal source and the negative energy signal could serve as a control switch inducing phase transition like process taking the excited atom like systems to ground state (induce emission). This process should occur in living matter. Anomalous excitation of atomic state by absorbing energy by remote metabolism and subsequent generation of radiation could also serve as a signature. It could also lead to cooling effects breaking second law.

Negative energy signals would also make possible realization of intentional action by initiating the activity already in geometric past. This would be very desirable in rapidly changing circumstances. The time anomalies of Libet for active aspect of consciousness could be interpreted in terms of time mirror mechanism [J1] and further experiments in longer time scales might be perhaps carried out.

Negative energy signals could be also essential for the mechanism of long term memory. They would induce a breakdown for a system analogous to population reversed laser via induced emission meaning generation of strong positive energy signal [K20].

2.2.5 Definition of energy in zero energy ontology

The approach relying on the two super conformal structures of quantum TGD gives hopes of defining the notion of energy for positive and negative energy parts of the state.

1. CD allows translational invariance only in its interior and since partonic two surfaces are located to the boundary of CD, one can argue that translations assigned to them lead out from CD. One can however argue that if it is enough to assign eigenstates of four-momentum to partons and require that only the total four-momentum generators acts on the physical state by shifting CD. Since total four-momentum vanishes for CD this would mean that wave function in cm degrees of CD is just constant plane wave. Super-conformal invariance would indeed allow to assign momentum eigenstates to the super-conformal representations.

2. A more stringent condition would be that four-momentum generators act as translation like operators on partons themselves. Since light-like 3-surfaces assignable to incoming and outgoing legs of the generalized Feynman diagrams are the basic objects, one can hope of having enough translational invariance to define the notion of energy. If translations are restricted to time-like translations acting in the direction of the future (past) then one has local translation invariance of dynamics for classical field equations inside $\delta M^4_{\pm}$ as a kind of semigroup. Also the M^4 translations leading to interior of X^4 from the light-like 2-surfaces surfaces act as translations. Classically these restrictions correspond to non-tachyonic momenta defining the allowed directions of translations realizable as particle motions. These two kinds of translations can be assigned to super-symplectic conformal symmetries at $\delta M^4_{\pm} \times CP_2$ and and super Super-Kac-Moody type conformal symmetries acting as super-symplectic isometries. Super-symplectic algebra is realized in terms of second quantized spinor fields and covariantly constant modes of right-handed neutrino. Symplectic group has as sub-group symplectic isometries and the Super-Kac-Moody algebra associated with this group and represented in terms of spinor modes localized to string world sheets plays also a key role in TGD.

   Finite M^4 translations to the interior of CD do not respect the shape of the partonic 2-surface. Local M^4 translations vanishing at the boundary of CD however act as Kac-Moody symmetries of the light-like 3-surfaces and reduce physically to gauge transformations: hence one could allow also the deformations of the partonic 2-surface in the interior of the light-like 3-surface. This corresponds to the effective metric 2-dimensionality stating that all information both about the geometry of WCW and quantum physics is carried by the partonic 2-surfaces X^2 resulting as intersections of the light-like 3-surfaces X^3_l and space-like 3-D surfaces X^3 at the boundaries of CD and the distribution of 4-D tangent planes of X^2.

3. The condition selecting preferred extremals of Kähler action is induced by a global selection of $M^2 \subset M^4$ as a plane belonging to the tangent space of X^4 at all its points [K5] and interpreted as a plane of nonphysical polarizations so that direct connection with number theory and gauge symmetries emerges. The M^4 translations of X^4 as a whole in general respect the form of this condition in the interior. Furthermore, if M^4 translations are restricted to M^2, also the condition itself - rather than only its general form - is respected. This observation, the earlier experience with p-adic mass calculations, and also the treatment of quarks and gluons in QCD encourage to consider the possibility that translational invariance should be restricted to M^2 translations so that mass squared, longitudinal momentum and transversal mass squared would be well defined quantum numbers. This would be enough to realize zero energy ontology. Encouragingly, M^2 appears also in the generalization of the causal diamond to a book-like structure forced by the realization of the hierarchy of Planck constant at the level of the embedding space.

4. That the cm degrees of freedom for CD would be gauge like degrees of freedom sounds strange. The paradoxical feeling disappears as one realizes that this is not the case for sub-CDs, which indeed can have non-trivial correlation functions with either upper or lower tip of the CD playing a role analogous to that of an argument of n-point function in QFT description. One can also say that largest CD in the hierarchy defines infrared cutoff.

2.2.6 Objection against zero energy ontology

In Zero Energy Ontology (ZEO), the basic geometric structure is causal diamond (CD), which is a subset of $M^4 \times CP_2$ identified as an intersection of future and past directed light cones of M^4

with points replaced with CP_2. Poincare symmetries are isometries of $M^4 \times CP_2$ but CD itself breaks Poincare symmetry.

Whether Poincare transformations can act as global symmetries in the "world of classical worlds" (WCW), the space of space-time surfaces - preferred extremals - connecting 3-surfaces at opposite boundaries of CD, is not quite clear since CD itself breaks Poincare symmetry. One can even argue that ZEO is not consistent with Poincare invariance. By holography one can either talk about WCW as pairs of 3-surfaces or about space of preferred extremals connecting the members of the pair.

First some background.

1. Poincare transformations act symmetries of space-time surfaces representing extremals of the classical variational principle involved, and one can hope that this is true also for preferred extremals. Preferred extremal property is conjectured to be realized as minimal surface property realize in terms of appropriately generalized holomorphy property meaning that field equations are separately satisfied for Kähler action and volume action apart from 2-D string world sheets and their boundaries to which one can assign the analog of Kähler action.

2. String world sheets and their light-like boundaries carry elementary particle quantum numbers identified as conserved Noether charges assigned with second quantized induced spinors solving modified Dirac equation determined by the action principle determining preferred extremals. Quantum classical correspondence (QCC) states that classical charges are equal to the eigenvalues of Poincare generators in Cartan algebra of Poincare algebra. This would hold quite generally.

3. The ground states of super-symplectic and super-Kac-Moody representations correspond to spinor harmonics with well-defined Poincare quantum numbers. Excited states are obtained using generators of symplectic algebra and have well-defined four-momenta identifiable also as classical momenta.

4. In ZEO one assigns opposite total quantum numbers to the boundaries of CD: this codes for the conservation laws. The action of Poincare transformations can be non-trivial at second (active) boundary of CD only and one has two kinds of realizations of Poincare algebra leaving either boundary invariant. Since Poincare symmetries extend to Kac-Moody symmetries analogous to local gauge symmetries it should be possible to achieve trivial action at passive boundary of CD so that the Cartan algebra of symmetries acts non-trivially only at the active boundary of CD. Physical intuition suggests that Poincare transformations on the entire CD treating it as a rigid body correspond to trivial center of mass quantum numbers.

How do the Poincare transformations act on 3-surfaces at the active boundary of CD?

1. Zero energy states are superpositions of 4-D preferred extremals connecting 3-D surfaces at boundaries of CD, the ends of space-time. One should be able to construct the analogs of plane waves as superpositions of space-time surfaces obtained by translating the active boundary of CD and 3-surfaces at it so that the size of CD increases or decreases. The translate of a preferred extremal is a preferred extremal associated with the new pair of 3-surfaces and has size and thus also shape different from those of the original. Classical theory becomes obviously an essential part of quantum theory.

2. Four-momentum eigenstate is an analog of plane wave which is superposition of the translates of a preferred extremal. In practice it is enough to have wave packets so that in given resolution one has a cutoff for the size of translations in various directions. As noticed, QCC requires that the eigenvalues of Cartan algebra generators such as momentum components are equal to the classical charges.

2.3 The Anatomy Of Quantum Jump In Zero Energy Ontology (ZEO)

Zero energy ontology (ZEO) emerged around 2005 and has had profound consequences for the understanding of quantum TGD. The basic implication is that state function reductions occur at the opposite light-like boundaries of causal diamonds (CDs) forming a hierarchy, and produce

zero energy states with opposite arrows of time. Also concerning the identification of quantum jump as moment of consciousness ZEO encourages rather far reaching conclusions. In ZEO the only difference between motor action and sensory representations is that the arrows of embedding space time (CDs) are opposite for them. Furthermore, sensory perception followed by motor action corresponds to a basic structure in the sequence of state function reductions and it seems that these processes occur fractally for CDs of various size scales.

1. State function reduction can be performed to either boundary of CD but not both simultaneously. State function reduction at either boundary is equivalent to state preparation giving rise to a state with well defined quantum numbers (particle numbers, charges, four-momentum, etc...) at this boundary of CD. At the other boundary single particle quantum numbers are not well defined although total conserved quantum numbers at boundaries are opposite by the zero energy property for every pair of positive and negative energy states in the superposition. State pairs with different total energy, fermion number, etc.. for other boundary are possible: for instance, the coherent states of super-conductor for which fermion number is ill defined are possible in zero energy ontology and do not break the super-selection rules.

2. The basic objects coding for physics are U-matrix, M-matrices and S-matrix. M-matrices correspond to hermitian square roots of density matrices multiplied by a universal S-matrix which depends on the scale n of CD in very simple manner: $S(n) = S^n$ giving thus a unitary representation for scalings. The explicit construction of a unitary U-matrix in terms of M-matrices is carried out in [K18]: U-matrix elements are essentially inner products of M-matrices associated with CDs with various size scales. One can say that quantum theory is formally a square root of thermodynamics. The thermodynamics in question would however relate more naturally to NMP rather than second law, which at ensemble level and for ordinary entanglement can be seen as a consequence of NMP.

   The non-triviality of M-matrix requires that for given state reduced at say the "lower" boundary of CD there is entire distribution of states at "upper boundary" (given initial state can lead to a continuum of final states). Even more, all size scales of CDs are possible since the position of only the "lower" boundary of CD is localized in quantum jump whereas the location of upper boundary of CD can vary so that one has distribution over CDs with different size scales and over their Lorentz boots and translates.

3. The quantum arrow of time follows from the asymmetry between positive and negative energy parts of the state: the other is prepared and the other corresponds to the superposition of the final states resulting when interactions are turned on: also quantum superposition over CDs of different sizes with second boundary belonging to the same fixed $\delta M^4_{\pm}$ is possible. What is remarkable that the arrow of time at embedding space level (at least) changes direction as quantum jump occurs to opposite boundary.

   It is however possible to have sequences of quantum jumps occurring at the same boundary: these periods are counterparts for repeated state function reductions, which do not change the state at all in standard quantum measurement theory. During these periods the superposition of opposite boundaries of CDs and states at them change, and the average distance between the tips of CDs tends to increase, hence the flow of subjective time and its arrow.

   NMP dictates when the first quantum jumps to the opposite boundary of CD takes place. The sequence of state function reduction at the same boundary defines self as a conscious entity and the increase of the average distance between the tips of CD defines the life-time of self.

   This brings strongly in mind the old proposal of Fantappie [J2] that in living matter the arrow of time is not fixed and that entropy and its diametric opposite syntropy apply to the two arrows of the embedding space time. The arrow of subjective time assignable to second law would hold true but the increase of syntropy would be basically a reflection of second law since only the arrow of the geometric time at embedding space level has changed direction. The arrow of geometric at space-time level which conscious observer experiences directly could be always the same if quantum classical correspondence holds true in the sense

that the arrow of time for zero energy states corresponds to arrow of time for preferred extremals. The failure of strict non-determinism making possible phenomena analogous to multi-furcations makes this possible.

4. This picture differs radically from the standard view and if quantum jump represents a fundamental algorithm, this variation of the arrow of geometric time should manifest itself in the functioning of brain and living organisms. The basic building brick in the functioning of brain is the formation of sensory representation followed by motor action/volition realized as the first reduction at the opposite boundary.

   These processes look very much like temporal mirror images of each other such as the state function reductions to opposite boundaries of CD look like. The fundamental process could correspond to a sequences of these two kinds of state function reductions at opposite boundaries of CDs and maybe independently for CDs of different size scales in a "many-particle" state defined by a union of CDs.

How the formation of cognitive and sensory representations could relate to quantum jump?

1. The earlier view was based on the idea that p-adic space-time sheets can transform to real ones and vice versa in quantum jump and these process correspond to a realization of intention as action and formation of though. This view is mathematically awkward and has been replaced with the adelic vision in which all systems have both sensory (real space-time sheets) and cognitive (p-adic space-time sheets) space-time correlates. The real and p-adic number fields form a book like structure - adele- with an algebraic extension of rationals as its back. Same applieds at the level of embedding space, space-time surfaces, and WCW. In this framedwork holography makes it possible to understand real and p-adic space-time surfaces as continuations of string world sheets and partonic 2-surfaces to space-time surfaces, either real or p-adic. The string world sheets themselves are in the intersection of reality and various p-adicities in the sense that the parameters characterizing them belong to an extension of rational numbers.

2. Self having the mental image about intention can be be seen as the agent transforming intention to action. By NMP negentropy is typically generated in this transition tending to increase the value of Planck constant $h_{eff} = n \times h$ and thus reducing quantum criticality and occurring therefore spontaneously. Negentropy Maximization Principle eventually forces the occurrence of volitional action - self experiences the urge to perform the action so strong that cannot resist. Subself representing the mental image about intention tries to prevent it as long as possible because it means death: all living systems try to stay at the existing level of criticality and avoid the fatal final state function reduction by practicing homeostasis and using metabolic energy. Weak form of NMP states that self has freedom to decide whether it performs the reduction producing maximal entanglement negentropy. It can also perform ordinary quantum jump reducing entanglement entropy to zero and destroying entanglement. The outcome is isolation from the external world. The motivation for the weak form of NMP is that we do not live in the best possible world and have free will to choose between Good and Evil. Strong form of NMP would produce always mazimal negentropy gain and would mean best possible world.ur in various length scales in fractal manner.

2.4 Conscious Entities And Arrow Of Time In TGD Universe

"Fractality from your blog" posed an interesting question about possible asymmetry between boundaries of causal diamond CD. The answer to the question led to recall once again the incomplete understanding of details about how the arrow of time emerges in zero energy ontology (ZEO).

The basic vision is following.

1. CDs form a fractal scale hierarchy. Zero energy states possess a wave function in moduli degrees of freedom characterizing sizes of CDs as well telling what Lorentz boost leaving boundary invariant are allowed for them. Boosts form by number theoretic constraints a discrete subgroup of Lorentz group defining analogs of lattices generated by boosts instead of translations.

2. The arrow of subjective time maps to that of geometric time somehow. The origin of arrow comes from the fact that state function reductions can occur to either boundary of given CD and reduction creates time-asymmetric state since second boundary of CD is in a quantum superposition of different sizes and there is a superposition of many-particle states with different particles numbers and quantum number distributions. It is possible that each state function reduction leaving the passive boundary intact, involves localization in the moduli space of CDs with second boundary fixed.

3. Subjective existence corresponds to a sequence *of moments of consciousness*: state function reductions at opposite boundaries of CDs. State function reduction localizes either boundary but the second boundary is in a quantum superposition of several locations and size scales for CD. This predicts that the arrow of time is not constant. In fact, there is considerable evidence for the variation of the arrow of time in living systems and Fantappie [J2] introduced long time ago the notion of syntropy to describe his view about the situation.

4. The first very naïve proposal was that state function reductions occur *alternately* to the two boundaries of CD. This assumption would be indeed natural if one considered single fixed CD rather than superposition CDs with different size and state function reduction localizing their either boundary: restriction to single CD was what I indeed did first.

5. This assumption leads to the question about why do we do not observe this alternation of the arrow of time all the time in our personal experience. Some people actually claim to have actually experienced a temporary change of the arrow of time: I belong to them and I can tell that the experience is frightening. But why do we experience the arrow of time as stable in the standard state of consciousness?

One possible way to solve the problem - perhaps the simplest one - is that state function reduction to the same boundary of CD can occur many times repeatedly. This solution is so absolutely trivial that I could perhaps use this triviality to defend myself for not realizing it immediately!

I made this totally trivial observation only after I had realized that also in this process the wave function in the moduli space of CDs change in these reductions. Zeno effect in ordinary measurement theory relies on the possibility of repeated state function reductions. In the ordinary quantum measurement theory repeated state function reductions do not affect the state in this kind of sequence but in ZEO the wave function in the moduli space labelling different CDs with the same boundary could change in each quantum jump. It would be natural that this sequence of quantum jumps give rise to the experience about flow of time? This option would allow the size scale of CD associated with human consciousness be rather short, say.1 seconds. It would allow to understand why we do not observe continual change of arrow of time.

Maybe living systems are working hardly to keep the personal arrow of time un-changed - living creatures try to prevent kettle from boiling by staring at it intensely. Maybe it would be extremely difficult to live against the collective arrow of time.

An objection against this picture as compared to the original one assuming alternate reductions to the opposite boundaries of CD is that is that one can understand state preparation as state function reduction to the opposite boundary. This interpetation makes sense almost as such also in the new picture if the average time period for which the reductions occur to a given boundary is shorter in elementary particles scales than in macroscopic scales characteristic for human consciousness. The approximate reversibility in elementary particle scales can be understood as summing up of the two arrows of time to no arrow at all.

This picture allows also to identify self as a continuous entity as the sequence of state function reductions occurring at the same boundary of CD. The average increase of the temporal distance between the tips of cD defines the life-time of self. The number of reductions would give a measure for the subjectively experienced of life-time of self.

In elementary particle time scales reversibility is a good approximation and this suggests that in elementary particle scales the number of state function reductions at the same boundary of CD is small so that the effects due to the change of the arrow of time cancel on the average.

NMP would eventually force "death" of self since the state function reduction at opposite boundary would generate more negentropy. "Death" of self would mean birth of self asssociated

with the opposite boundary of CD. The age of self identified as the proper time distance between the tips would increase in statistical sense even when its arrow can change. The act of volition would have a natural identification as the first state function reduction at the opposite boundary of CD.

This picture raises a series of questions. Do our wake-up periods correspond to sequences of state function reductions for self and are sleeping periods wake-up periods of the self at the opposite boundary of CD? The arrow of geometric time should change at some space-time sheet associated with the self hierarchy. How could one demonstrate this? Are the memories of the "other" self predictions of future from our point of view? Do we sleep in order to get information from future, to remember what the future will be?

How the hierarchy of Planck constants defining a hierarchy of quantum criticalities does relate to this picture? The ageing of self having has as a correlate the increase of the size scale of CD. Could this increase be due to the increase of h_{eff} expected to occur spontaneously since it corresponds to a reduction of criticality and therefore to the appearance of new physical degrees of freedom as symplectic gauge degrees of freedom transform to physical ones in gauge symmetry breaking. This is not the case. The time evolution must be analogous to shift in time rather than scaling. This of course corresponds to the QFT view about time evolution.

In the first state function reduction to the opposite boundary of CD however scaling of CD is possible and would correspond to the scaling of CD represented by exponent of infinitesimal scaling operator as in conformal field theories. The emergence of bew physical degrees of freedom suggest increasing perceptive and cognitive capabilities. The increase of h_{eff} could be seen as evolution as also the associated increase of resources of negentropic entanglement suggests. The total increase of h_{eff} measured by the ratio $h_{eff}(final)/h_{eff}(initial)$ could be seen as a measure for the progress per single life period of self.

2.5 Copenhagen interpretation dead: long live ZEO based quantum measurement theory!

I encountered a very interesting ScienceDaily article "*Physicists can predict the jumps of Schrödinger's cat (and finally save it)*" (see `http://tinyurl.com/y5lpe2eo`). The experimental findings described in the article are extremely interesting from the point of view provide by TGD inspired quantum measurement theory relying on Zero Energy Ontology (ZEO) and provides a test for it.

In standard quantum measurement theory (Copenhagen interpretation) of Bohr quantum jump is random in the sense that it occurs with predictable probabilities to an eigenstate of the measured observables. Their occurrence cannot be predicted and even less prevented - except by monitoring - Zeno effect.

The findings of Minev *et al* are described in the article "*To catch and reverse a quantum jump mid-flight*" [L25] (see `https://arxiv.org/abs/1803.00545`). The outcome of quantum jump is indeed unpredictable but the time of occurrence is to high degree predictable: there is a detectable warning signal, period of "flight" from the initial to the final state!

A curious feature is that the external signal responsible for the quantum jump can be stopped during the "flight" from the initial to final state. As if the quantum jump is analogous to a domino effect. It is also claimed that the jump can be reversed during flight period by a control signal: if jump has already occurred then one might argue that the control signal induces quantum jump in opposite direction when applied at time which is roughly the mid-time of "flight".

If the findings by Minev *et al* are replicable, one is forced to give up the basic assumption of the standard quantum measurement theory stating that state function reductions occur completely randomly and instantaneously. State function reduction (SR) looks like a continuous, deterministic process. Bohr's theory would be dead also officially and one must finally go back to the blackboard and start serious thinking about fundamentals. It took 92 years - almost a century! State function reduction (SR) is definitely more complex phenomenon than predicted by Bohr.

What is most intriguing that SR looks smooth, deterministic classical time evolution although the outcome is not predictable. People loving hidden variables might be happy but better to think about this more precisely before jumping to any conclusions. Authors apply so called quantum trajectory theory to describe the findings [B3] and report that the model is able to predict the parameters of the parameterization with one per cent accuracy.

Zero energy ontology (ZEO) based view about quantum measurement and the relationship between geometric and subjective time explains why state function reduction looks like a deterministic process. Unfortunately, what ZEO is, is not completely clear [L28]. This allows to consider two options.

1. Both options imply that one can apparently anticipate quantum jump. This could be however an illusion: the observed classical time evolution could occur *after* the quantum jump in opposite direction of time. The fact that the absence of the signal inducing quantum jump does not affect the occurrence of quantum jump suggests that the "flight" period indeed represents the classical evolution after the quantum jump in the reversed direction of time so that the absence of the external signal would not anymore affect the situation. Generalized Zeno effect is essential element ZEO based quantum measurement theory so that SR might be prevented. Perhaps a more plausible interpretation is that the control signal induces the reversal of the quantum jump already occurred. A careful analysis to distinguish between subjective and geometric time and arrows of time for the observer and atom would be needed.

2. The more conventional option nearer to the interpretation of experimenters is that the observed time evolution occurs *before* the quantum jump in standard direction. The period before quantum jump consists of a sequence of "small" state function reductions - "weak" measurements. $M^8 - H$ duality suggests a concrete assignment of the moments of time to them [L28] and there would be also the last moment of this kind. After these things proceed to "big" state function reduction in analogy with domino effect. It is not however obvious why the classical time evolution should appear to converge to the final outcome deterministically.

2.5.1 First ZEO based based view about the findings

What about TGD and zero energy ontology (ZEO) based quantum measurement theory [K18]? Could it explain the revolutionary findings?

1. The new element is that quantum states are not time= constant snapshots for time evolution but superpositions of entire deterministic time evolutions at the level of space-time surfaces and at the level of induced spinor fields. SR replaces super position of classical time evolutions with a new one. This like selecting and starting new deterministic computer program. Non-determinism is in these choices [L18].

2. The notion of causal diamond (CD) identified as an intersection of future and past directed light-cones of M^4 with points replaced with CP_2 is crucial. The notion of CD is strongly suggested by the gigantic symmetries of CD essential for the construction of quantum TGD. CD could be seen as embedding space correlate for the perceptive field of a conscious entity - self. The upper boundary of CD - to be called active boundary A represents the boundary for space-time region from which self can receive classical signals and is therefore natural. The lower boundary, to be called passive boundary B, brings in mind cosmic expansion and follows as a prediction from $M^8 - H$ duality.

3. There are two kinds of state function reductions in ZEO.

   (a) In "small" SRs (SSRs) the states change at active boundary of causal diamond (CD) (call it A) but remain unchanged at passive boundary (call it P): generalized Zeno effect occurs at the passive boundary and "weak measurements" (see `http://tinyurl.com/zt36hpb`) at A. The observables measured commute with those determining the states at P as their eigenstates. In particular, the location of A is measured localizing it and corresponds to the measurement of time as distance between the tips of CD.

   "Big" SRs (BSRs) reverse the arrow of time of zero energy states and the roles of A and P. BSR is preceded by a sequence of SSRs - "weak" or almost classical measurements. In TGD inspired theory of consciousness [L18, L28] [K14] this sequence defines the life cycle of a conscious entity - self.

What is of crucial importance that BSR creates the illusion that it is an outcome of a continuous process: this realizes quantum classical correspondence (QCC). Standard observer assumes

standard arrow of time and the space-time surfaces in the final time reversed state seem to lead to the 3-surface serving as a correlate for the final state! As if BSR would be outcome of a smooth deterministic process, which it is not! There is actually a superposition of these 3-surfaces at A after BSR but in the resolution used this is not detected. Putting it more precisely:

1. The time reversal of time evolution is in good approximation obtained by time reflection symmetry T but not quite since T is slightly broken. This is extremely small effect.

2. Before BSR one has a distribution of 3-surfaces X^3 defining the ends of space-time surfaces X^4 at A: 3-surfaces X^3 corresponds to different outcomes of BSR and can differ dramatically. Observer is not conscious of this. This is like a situation of Schrödinger cat before measurement: it is impossible to be conscious about the superposition of dead and alive cat.

   After BSR one has quantum superposition of space-time surfaces directed to geometric past. Near the end of space-time at A they look like leading to a unique classical counterpart of final state of state function reduction. As if the state function reduction were a smooth, continuous, deterministic process. BSR guarantees this but BSR is not a smooth evolution.

The experimental findings could be understood by applying this general picture.

1. One can assign to the evolution from initial state G of atom at P to final state E at A a sequence of small reductions, weak measurements and also superposition of classical time evolutions approximated by single evolution in given measurement resolution. The state E is superposition of various measurement outcomes and each of them corresponds to a superposition of space-time surfaces identical in the measurement resolution used.

2. Then occurs the BSR: atom jumps from state E to state D. This selects from the superposition of space-time surfaces/time only the evolutions apparently leading to D. Or more precisely: the superposition of reversed time evolutions starting from D at A and very similar near A but deviating farther from it. The illusion about continuous, smooth, deterministic time evolution from G to D is created!

3. Also the possibility to anticipate the reduction would be an illusion due to the different arrows of time for observer and the observed system after BSR. The time reversed time evolution actually starts from the final state. The warning signal (absence of photon emission would be natural consequence of the reduction but in reversed arrow of time. The illusion would be due to the identification of arrows of time of observer and the atom that made state function reduction. This conforms with the observation that one can drop away the periodic signal inducing the quantum jumps during the "flight" period identified as the deterministic process representing the quantum jump.

   The lesson would be that one must always check whether the arrow of time for the target of attention is same as my own. Not a good idea to be on the wrong lane (means death also in ZEO based consciousness theory).

   It is also claimed that on can prevent the quantum jump using a signal during the "flight" period. Generalized Zeno effect is basic element of TGD but the signal forcing the state to remain in P would be present before the quantum jump. This would suggest that the control signal induced quantum jump in opposite direction. To really understand the situation a careful analysis of the relationships between subjective and geometric times of observer and between geometric time of observer and atomic system after and before the quantum jump would be needed.

Also Libet's findings about active aspects of consciousness [J1] can be interpreted in ZEO along the same lines. The observation that the neural activity begins before conscious decision can be understood by saying that the act of free will as a big state function reduction changed the arrow of time for an appropriate subsystem of the system studied. Tte time reversed classical evolutions from the outcome of the volitional action were interpreted erratically as a time evolution leading to the conscious decision. A less precise manner to say this is that conscious decision (big state function reduction) sent a classical signal to geometric past with opposite arrow of time initiating

neural activity. Libet's finding led physicalistic neuroscientists to conclude that free will is an illusion. The actual illusions were physicalism and the belief that arrow of time is always the same.

To sum up, ZEO is fantastic magician. Maybe this magic is necessary for the mental health of observer: a world without this illusion would be like nightmare where one cannot trust anything.

2.5.2 Second ZEO based based view about the findings inspired by $M^8 - H$ duality

I have learned to take experimental findings very seriously and I am ready to aks whether the above described option the only possibility allowed by ZEO or can one think other alternatives? It would be nice to answer "No" but one can consider variants of ZEO [L28] inspired by so called $M^8 - H$ duality [L11, L39].

The sequence of "small" state function reductions (SSRs) should have the last one. Is the "big" state function reduction (BSR) forced by some condition? One idea is that the life cycle of self corresponds to a measurement of all observables assignable to the active boundary A of CD and commuting with those defining the unaffected states at passive boundary P are measured (time as a location of A belongs to these observables measured in each SSR).

I have discussed in [L28] possible modifications of ZEO inspired by so called $M^8 - H$ duality [L11, L39]. One motivation is that time flow as shifting M^4 time $t = constant$ hyper-plane can be argued to be more natural than that for light-cone boundary. Light-cone boundaries are however favored by its huge symmetries essential for the definition of the geometry of "world of classical worlds" (WCW). $M^8 - H$ duality forces passive light-cone boundary P and the identification of A as boundary of region where sensory signals can arrive to self is natural.

$M^8 - H$ duality allows to consider variants the original ZEO.

1. $M^8 - H$ duality

Let us first briefly summarize what $M^8 - H$ duality [L11] is.

1. $M^8 - H$ duality is one of the key ideas of TGD, and states that one can regard space-times as surfaces in either complexified octonionic M^8 or in $M^4 \times CP_2$. The dynamics M^8 is purely algebraic and requires that either tangent or normal space of space-time surface is associative (quaternionic).

2. The algebraic equations for space-time surfaces in M^8 state the vanishing of either the real or imaginary part (defined in quaternionic sense) for octonion valued polynomial $P(o)$ with real coefficients. Besides 4-D roots one obtains as universal exceptional roots 6-spheres at boundary of the light-cone of M^8 with radii given by the roots r_n of the polynomial in question. They correspond to the balls $t = r_n$ (t is octonionic real coordinate) inside Minkowski light-cone with each point have as fiber a 3-sphere S^3 with radius contracting to zero at the boundary of the light-cone of M^4. These 6-spheres are clearly analogous to branes connected by 4-D space-time surfaces.

3. The intersections of space-time surfaces with 6-spheres would be 2-D and I have interpreted them as partonic 2-surfaces identifiable as topological particle reaction vertices - partonic 2-surfaces - at which incoming and outgoing light-like 3-surfaces meet along their ends. These light-like 3-surfaces - partonic orbits - would represent the boundaries between space-time regions with Euclidian and Minkowskian signatures of the induced metric. Partonic 2-surfaces would be analogs of the vertices of Feynman diagrams. The boundaries of string world sheets predicted as singularities of minimal surfaces defining space-time surfaces would be along the partonic orbits and give rise to QFT type description using cognitive representations and analogs of twistor diagrams consisting of lines.

2. $M^8 - H$ duality and consciousness

One can ask whether $M^8 - H$ duality and this braney picture has implications for ZEO based theory of consciousness. Certain aspects of $M^8 - H$ duality indeed challenge the recent view about consciousness based on ZEO (zero energy ontology) and ZEO itself.

1. The moments $t = r_n$ defining the 6-branes correspond classically to special moments for which phase transition like phenomena occur. Could $t = r_n$ have a special role in consciousness theory?

(a) For some SSRs the increase of the size of CD reveals new $t = r_n$ plane inside CD. One can argue that these SSRS define very special events in the life of self. This would not modify the original ZEO considerably but could give a classical signature for how many ver special moments of consciousness have occurred: the number of the roots of P would be a measure for the lifetime of self and there would be the largest root after which BSR would occur.

(b) Second possibility is more radical. One could one think of replacing CD with single truncated future- or past-directed light-cone containing the 6-D universal roots of P up to some r_n defining the upper boundary of the truncated cone? Could $t = r_n$ define a sequence of moments of consciousness? To me it looks more natural to assume that they are associated with very special moments of consciousness.

2. For both options SSRs increase the number of roots r_n inside CD/truncated light-one gradually and thus its size? When all roots of $P(o)$ would have been measured - meaning that the largest value r_{max} of r_n is reached -, BSR would be unavoidable.

   BSR could replace $P(o)$ with $P_1(r_1 - o)$: r_1 must be real and one should have $r_1 > r_{max}$. The new CD/truncated light-cone would be in opposite direction and time evolution would be reversed. Note that the new CD could have much smaller size size if it contains only the smallest root r_0. One important modification of ZEO becomes indeed possible. The size of CD after BSR could be much smaller than before it. This would mean that the re-incarnated self would have "childhood" rather than beginning its life at the age of previous self - kind of fresh start wiping the slate clean.

   One can consider also a less radical BSR preserving the arrow of time and replacing the polynomial with a new one, say a polynomial having higher degree (certainly in statistical sense so that algebraic complexity would increase).

3. Is a more conservative view possible?

Could this picture allow to build a more conservative picture more akin to that proposed by experimenters?

1. The interpretation of the detected time evolution as that *before* the quantum jump would conform with the interpretation of experimentalists that a kind of domino effect is involved and also with the observation that stopping the signal causing the quantum jumps does not anymore affect the situation.

2. It is however unclear how to understand why the evolution looks like leading to the outcome unless the sequence of r_n:s defines a sequence of steps gradually taking the system near the final state.

3. What about preventing the BSR by external signal and even reversing the quantum jump? This would require an external perturbation of the octonionic polynomial increasing the value of the largest root r_{max} or even the degree of the polynomial and bringing in additional significant moments of life. Is it possible to speak about external perturbations of the coefficients of polynomials assumed to be rational numbers? The perturbations would come from a higher level in the hierarchy of selves (experimentalist), and one can imagine them in the framework of many-sheeted space-time.

To sum up, to my opinion (which could change) the first option looks more plausible. The introduction of moments $t = r_n$ as special moments in the life of self looks highly attractive and also the possibility of wiping the slate clear.

2.6 Could ZEO allow over-unity effects and quantum error correction mechanism?

The notion of free energy used by free energy researches is different from the standard notion of free energy appearing in thermodynamics. Free energy researchers typically claim over-unity effects.

In strong form it would mean non-conservation of energy and academic community concludes that since energy is conserved, these claims are crackpot non-sense. In weaker form the claims would mean transformation of heat to work with efficiency larger than the upper bound predicted by Carnot law.

Second law kills hopes about perpetual motion machines based on this kind of over-unity effects. Second law however assumes fixed arrow of time. There exists however strong empirical evidence for the possibility that the arrow of time can change - phase conjugate waves are the key example. This led Fantappie [J2] to propose the notion of syntropy as entropy in reversed time direction. Second law in reverse time direction could also allow an error correction mechanism in quantum computation: Nature itself would do it. Phase conjugate waves are indeed known to perform error correction.

Quantum TGD relies on zero energy ontology (ZEO). ZEO allows both arrows of time and a temporary change of the arrow of time could make possible to break the standard laws of thermodynamics at least temporarily and in short enough scales. ZEO indeed plays a key role in TGD inspired quantum biology and quantum theory of consciousness.

In the following I will consider the issue of energy conservation in ZEO. Classically energy is well-defined and conserved in TGD Universe. But what about energy conservation in quantum sense? ZEO involves delocalization of states in time and this could allow energy conservation only in some resolution determined by the scale of the increment of time in given state function reduction inducing a shift of the active boundary of CD farther from the passive one.

2.6.1 Energy is conserved classically in TGD but what about conservation in quantum sense in ZEO?

ZEO guarantees classical conservation laws. What about the situation at quantum level? Could the energy associated with the positive energy part of zero energy state increase in quantum transitions and lead to over-unity effects? In principle, conservation laws do not prevent this quantally.

1. Recall that zero energy states [K18] [L18] are identified as superpositions of pairs (a, b) formed from states a and b having opposite total quantum numbers and being assigned with the opposite boundaries of causal diamond (CD). The states at the passive boundary B of CD are not affected whereas the states at the active boundary A are affected by a sequence of unitary time evolutions also shifting A farther away from B (in statistical sense at least).

   Each unitary evolution induces a de-localization of A in its moduli space and "small" SFR induces its localization (including time localization meaning time measurement). This sequence would approximately conserve the energies of the states in the superposition. This in the approximation that their energies are large in the energy scale $\Delta E = \hbar_{eff}/Deltat$ defined by the time increment Δt in single unitary time evolution. Large value of h_{eff} makes the conservation worse for a given Δt. Unitarity together with the approximate energy conservation implies that the average energy is approximately conserved.

2. Negative energy signals sent from A to its geometric past and received at B in remote metabolism would correspond to "big" SFR. If the notion of remote metabolism giving effectively rise to over-unitary effect is to make sense, the approximate energy conservation should fail in "big" SFRs in quantal sense. For this to be the case, the first unitary evolution of B followed by "small" SFR energy conservation should be a bad approximation. This does not however seem plausible if one assumes energy conservation for the next state function reductions. What could be so special in the first state function reduction?

3. Why the energy conservation made approximate by the finite size of CD and finite duration of unitary evolution, should fail badly in some situations? According to the number theoretic vision [L16], "small" SFRs preserve the extension of rationals defining the adele and therefore also $\hbar_{eff}/\hbar_0 = n$ identifiable as the dimension of the extension. $\hbar_{eff}/\hbar_0 = n$ can however change $n_{old} \to n_{new}$ in "big" SFRs forced to occur when "small" SFRs preserving n_{old} are not anymore possible. If a large increase of h_{eff} occurs in the "big" SFR, the $\Delta E = \hbar_{eff}/Deltat$ increases if Δt is still of the same order of magnitude. The approximate energy conservation could fail badly enough to make possible remote metabolism.

4. In the subsequent SFRs energy conservation should however hold true in good approximation. The values of Δt should be large in the subsequent "small" SFRs, and Δt should scale as $\Delta t \propto n$ to guarantee that ΔE remains the same. As a quantum scale Δt analogous to Compton length is indeed proportional to n. In the first reduction one must have of $n = n_{old}$ but in the subsequent reductions one must have $n = n_{new}$ to guarantee energy conservation in the same approximation as before.

   To sum up: in the first "small" SFR one should have $\Delta E \propto n_{new}$ and $\Delta t \propto n_{new}$. Can one really deduce this from the basic TGD?

5. ZEO suggests that evolution [L19] means a continual increase of the size of CD so that arbitrarily small CD could eventually grow to even cosmic size (whether this occurs always or whether zero energy state can become pure vacuum at both boundaries of CD remains an open problem). CD with a cosmic size should however have huge energy. This would not only require non-conservation of energy in quantal sense but also its increase in statistical sense at least. Why should the energy increase?

   The increase would relate directly to the basic defining property of ZEO. Preferred time direction means that the transfer of quantum numbers, in positive energy with fixed sign, can take place only from the active boundary of CD to the passive boundary in "big" SFR. This allows interpretation as remote metabolism implying increase of the magnitude of energy.

2.6.2 Criticism

Quite recently (towards end of 2019) I found a more precice formulation for the intuitive notion of remote metabolism, which strongly suggests that energy is conserved in ZEO. There is a decomposition to system and the energy energy source: call them A and B. Intuitively, A receives energy from B by sending negative energy to B. What does this really mean?

1. A "big" state function reduction reversing arrow of time takes place: this would correspond to sending negative energy signal to past. The energy of A+B in the final time reversed state at new passive boundary of CD would be shared in new manner such that one can say that A has received from B the metabolic energy.

2. Energy would be conserved. I have also considered the interpretation that the total energy of the system associated with CD increases [K18] [L37]: since CD itself breaks Poincare invariance, it seems that one cannot exclude this. However, the Poincare invariance is realized at the level of moduli space for the positions of the either boundary of CD, and one can assume energy conservation. Even the wave functions at the boundary of CD can be taken to be in the representations of Lorentz group acting as its isometries. Plane waves correspond to wave functions in the moduli space for the boundary of CD keeping second boundary fixed.

3. To make this more precise one must define metabolic energy more precisely by introducing the hierarchy of Planck constants and the fact that the increase of h_{eff} of sub-system keeping other parameters constant increases it energy. Second law means that A tends to loose energy due to the decrease of h_{eff} for its sub-systems. This is true also for the time-reversed state but in opposite direction of geometric time so that with respect to standard direction of time the energy increases. This would provide extremely general purely thermodynamical mechanism of remote metabolism.

2.6.3 Could Nature provide an error correction mechanism for quantum computation?

Error correction has turned out to be major problem in the attempts to construct quantum computers. It is believed to be necessary because quantum entanglement is extremely fragile for the standard value of Planck constant. In TGD the situation changes. Large values of h_{eff} increasing the time scale of entanglement are possible and reversed time evolutions in quantum sense imply second law in reversed time direction meaning spontaneous reduction of entropy in the standard time direction. Nature itself would provide the needed error correction mechanism perhaps applied routinely in living systems (for instance, to correct mutations of DNA and transcription and translation errors).

To sum up, this picture is extremely interesting from the point of view of future technologies. One can even challenge the cherished law of energy conservation at quantum level (classically it remains exact in TGD Universe). Could one consider the possibility that the energy of system could be increased by the evolution by "big" state function reductions increasing the value of h_{eff}? Could one at least temporarily reduce entropy by inducing time evolutions in opposite time direction? TGD strongly suggests that these mechanisms are at work in biology. Maybe energy and iquantum nformation technologists could learn something from living matter?

2.7 Ballistic resonance and zero energy ontology

The popular article "*Scientists have discovered a new physical paradox*" (`https://cutt.ly/lp6VL4l`) tells about the work of Vitaly A. Kuzkin *et al* published in Phys Rev E (`https://cutt.ly/Jp8XHYY`) as an article [D4] with title "*Ballistic resonance and thermalization in the Fermi-Pasta-Ulam-Tsingou chain at finite temperature*" . The article describes very interesting experimental findings, which could provide a direct application of zero energy ontology (ZEO) based theory of self-organization.

2.7.1 The findings and their explanation provided by experimenters

Researchers from the Peter the Great St. Petersburg Polytechnic University (SPbPU) have discovered a new physical effect: the amplitude of mechanical vibrations can grow without external influence in which system converts its thermal energy to mechanical energy. The phenomenon is known as ballistic resonance. The description of the phenomenon involves also an abnormally high heat conductivity - one speaks of ballistic heat conductivity.

The electromagnetic analogy is very high electric conductivity: the work of Bandyopadhyay related to effects of oscillating voltage on currents flowing along microtubules demonstrates ballistic conductivity possibly reflecting underlying super-conductivity [L3].

This behavior seems to be in conflict with second law of thermodynamics telling that the vibrations should be attenuated. The researchers propose also a theoretical explanation of this paradox (`https://cutt.ly/Cp6V52j`) based on a model assuming ballistic heat conduction. One can of course wonder whether the notion of ballistic heat conduction is consistent with second law in its standard form.

Fermi-Past-Ulam-Tsingou problem (`https://cutt.ly/cp8CxtA`) was a finding about a theoretical model of a vibrating string with a non-linear dynamics. The expectation was that the situation develops ergodic so that energy is evenly divided between the modes of the string. It however turned out that the behavior was essentially periodic. The model explaining the behavior relies on solitons assignable to Korteveg-de-Vries equation. This phenomenon is different from the ballistic resonance observed in the experiments. In Korteveg de-Vries equation there is no dissipative term and the unexpected phenomenon is that wave pattern preserves it shape. Dissipation without energy feed would attenuate the wave.

2.7.2 ZEO based model for the findings

TGD suggests that a genuine explanation requires a profound change in the thinking about time- in particular the relationship between geometric time and experienced time must be updated. I call the new conceptual framework zero energy ontology ZEO) [L35]. The identification of these two times in standard ontology is in conflict with simple empirical facts, and leads to a paradox related to state function reduction (SFR) taking place in quantum measurement. The non-determinism of SFR is in conflict with the determinism of Schrödinger equation.

1. According to ZEO in ordinary state function reduction (SFR) the arrow of time subsystem changes: this solves the basic paradox of quantum measurement theory. The experiments of Minev *et al* [L25] give impressive experimental support for the notion in atomic scales, and sow that SFR looks completely classical deterministic smooth time evolution for the observer with opposite arrow of time. This is just what TGD predicts. Macroscopic quantum jump can occur in all scales but ZEO takes care that the world looks classical! The endless debate about the scale in which quantum world becomes classical would be solely due to complete misunderstanding of the notion of time.

2. Non-standard arrow of time forces a generalization of thermodynamics. For time reversed system generalized second law applies in reverse direction of time. Dissipation with reversed arrow of time extracts energy from environment, in particular thermal energy from internal thermal environment. The energy feed necessary for self-organization reduces to dissipation in reversed arrow of time.

   This explains why self-organization is possible [L31]. Standard form of the second flow would imply that also energy flows between systems go to zero: this would mean thermodynamical equilibrium everywhere - heat death. This has led to desperate theoretical proposals such as life as gigantic thermodynamical fluctuation. The recent empirical understanding suggests that this giant fluctuation would have occurred in the scale of the entire Universe and continue forever!

3. Macroscopic quantum coherence is however a necessary prerequisite for macroscopic effects. TGD predicts hierarchy of phases of ordinary matter residing at magnetic body (MB) of the system with value of effective Planck constant $h_{eff} = nh_0$ ($h = 6h_0$) of h_{eff} behaving like dark matter and controlling ordinary matter. The larger the value of h_{eff}, the longer the scale of quantum coherence scale at MB. MB acts as master for ordinary matter in the role of slave and induces coherent behaviour. This gives rise to self-organization.

This picture could explain the observations of self induced resonance using thermal energy. A subsystem or its MB in time reversed mode would extract the thermal energy. There are many other applications. The phenomenon of stochastic resonance in which system extracts energy from external noise could have explanation along these lines. Stochastic resonance plays an important role in sensory perception by making possible amplification of weak signal in large background. There is evidence for it even in astrophysical scales. In biology metabolic energy could be extracted from metabolites and maybe also from thermal energy by time reversed dissipation by some subsystems related to metabolism.

TGD picture does not exclude the possibility of delicate models mimicking this behavior in the framework of thermodynamics. The basic challenge in this kind of effective model is to describe the presence time reversed dissipation inducing self-organization and the presence of dark matter at magnetic body phenomenologically. Energy feed as parameter gives rise to states far from thermodynamical equilibria.

For instance, the thermodynamics of ion distributions inside and outside cell is far far from thermodynamical equilibrium and and non-equilibrium thermodynamics has been developed for the modelling of this kind of systems utilizing the notions of ionic pumps and channels. The phenomenological description introduces chemical potentials as parameters to describe the non-equilibrium situation in the framework ordinary thermodynamics. Chemical potentials would model the neglected presence of $h_{eff} \geq h$ phases of dark matter at magnetic body of the system.

2.8 $M^8 - H$ duality and consciousness

$M^8 - H$ duality is one of the key ideas of TGD and one can ask whether it has implications for TGD inspired theory of consciousness and it indeed forces to challenge the recent ZEO based view about consciousness [L18] .

2.8.1 Objections against ZEO based theory of consciousness

Consider first objections against ZEO based view about consciousness.

1. ZEO (zero energy ontology) based view about conscious entity can be regarded as a sequence of "small" state function reductions (SSRs) identifiable as analogs of so called weak measurements at the active boundary of causal diamond (CD) receding reduction by reduction farther away from the passive boundary, which is unchanged as also the members of state pairs at it. One can say that weak measurements commute with the observables, whose eigenstates the states at passive boundary are. This asymmetry assigns arrow of time to the self having CD as embedding space correlate. "Big" state function reductions (BSRs) would change the roles of boundaries of CD and the arrow of time. The interpretation is as death and re-incarnation of the conscious entity with opposite arrow of time.

The question is whether quantum classical correspondence (QCC) could allow to say something about the time intervals between subsequent values of temporal distance between weak state function reductions.

2. The questionable aspect of this view is that $t_M = constant$ sections look intuitively more natural as seats of quantum states than light-cone boundaries forming part of CD boundaries. The boundaries of CD are however favoured by the huge symplectic symmetries assignable to the boundary of M^4 light-cone with points replaced with CP_2 at level of H. These symmetries are crucial or the existence of the geometry of WCW ("world of classical worlds").

3. Second objection is that the size of CD increases steadily: this nice from the point of view of cosmology but the idea that CD as correlate for a conscious entity increases from CP_2 size to cosmological scales looks rather weird. For instance, the average energy of the state assignable to either boundary of CD would increase. Since zero energy state is a superposition of states with different energies classical conservation law for energy does not prevent this [L37]: essentially quantal effect due to the fact that the zero energy states are not exact eigenstates of energy could be in question. In BSRs the energy would gradually increase. Admittedly this looks strange and one must be keen for finding more conventional options.

4. Third objection is that re-incarnated self would not have any "childhood" since CD would increase all the time.

One can ask whether $M^8 - H$ duality and this braney picture has implications for ZEO based theory of consciousness. Certain aspects of $M^8 - H$ duality indeed challenge the recent view about consciousness based on ZEO (zero energy ontology) and ZEO itself.

1. The moments $t = r_n$ defining the 6-branes correspond classically to special moments for which phase transition like phenomena occur. Could $t = r_n$ have a special role in consciousness theory?

   (a) For some SSRs the increase of the size of CD reveals new $t = r_n$ plane inside CD. One can argue that these SSRS define very special events in the life of self. This would not modify the original ZEO considerably but could give a classical signature for how many ver special moments of consciousness have occurred: the number of the roots of P would be a measure for the lifetime of self and there would be the largest root after which BSR would occur.

   (b) Second possibility is more radical. One could one think of replacing CD with single truncated future- or past-directed light-cone containing the 6-D universal roots of P up to some r_n defining the upper boundary of the truncated cone? Could $t = r_n$ define a sequence of moments of consciousness? To me it looks more natural to assume that they are associated with very special moments of consciousness.

2. For both options SSRs increase the number of roots r_n inside CD/truncated light-one gradually and thus its size? When all roots of $P(o)$ would have been measured - meaning that the largest value r_{max} of r_n is reached -, BSR would be unavoidable.

   BSR could replace $P(o)$ with $P_1(r_1 - o)$: r_1 must be real and one should have $r_1 > r_{max}$. The new CD/truncated light-cone would be in opposite direction and time evolution would be reversed. Note that the new CD could have much smaller size size if it contains only the smallest root r_0. One important modification of ZEO becomes indeed possible. The size of CD after BSR could be much smaller than before it. This would mean that the re-incarnated self would have "childhood" rather than beginning its life at the age of previous self - kind of fresh start wiping the slate clean.

   One can consider also a less radical BSR preserving the arrow of time and replacing the polynomial with a new one, say a polynomial having higher degree (certainly in statistical sense so that algebraic complexity would increase).

2.8.2 Could one give up the notion of CD?

A possible alternative view could be that one the boundaries of CD are replaced by a pair of two $t = r_N$ snapshots $t = r_0$ and $t = r_N$. Or at least that these surfaces somehow serve as correlates for mental images. The theory might allow reformulation also in this case, and I have actually used this formulation in popular lectures since it is easier to understand by laymen.

1. Single truncated light-cone, whose size would increase in each SSR would be present now since the spheres correspond to balls of radius r_n at times r_n. If $r_0 = 0$, which is the case for $P(o) \propto o$, the tip of the light-cone boundary is one root. One cannot avoid association with big bang cosmology. For $P(0) \neq r_0$ the first conscious moment of the cosmology corresponds to $t = r_0$. One can wonder whether the emergence of consciousness in various scales could be described in terms of the varying value of the smallest root r_0 of $P(o)$.

   If one allows BSR:s this picture differs from the earlier one in that CDs are replaced with alternation of light-cones with opposite directions and their intersections would define CD.

2. For this option the preferred values of t for SSRs would naturally correspond to the roots of the polynomial defining $X^4 \subset M^8$. Moments of consciousness as state function reductions would be due to collisions of 4-D space-time surfaces X^4 with 6-D branes! They would replace the sequence of scaled CD sizes. CD could be replaced with light-one and with the increasing sequence $(r_0, ...r_n)$ of roots defining the ticks of clock and having positive and negative energy states at the boundaries r_0 and r_n.

3. What could be the interpretation for BSRs representing death of a conscious entity in the new variant of ZEO? Why the arrow of time would change? Could it be because there are no further roots of $P(o)$? The number of roots of $P(o)$ would give the number of small state function reductions?

   What would happen to $P(o)$ in BSR? The vision about algebraic evolution as increase of the dimension for the extension of rationals would suggest that the degree of $P(o)$ increases as also the number of roots if all complex roots are allowed. Could the evolution continue in the same direction or would it start to shift the part of boundary corresponding to the lowest root in opposite direction of time. Now one would have more roots and more algebraic complexity so that evolutionary step would occur.

   In the time reversal one would have naturally $t_{max} \geq r_{n_{max}}$ for the new polynomial $P(t-t_{max})$ having $r_{n_{max}}$ as its smallest root. The light-cone in M^8 with tip at $t = t_{max}$ would be in opposite direction now and also the slices $t - t_{max} = r'_n$ would increase in opposite direction! One would have two light-cones with opposite directions and the $t = r_n$ sections would replace boundaries of CDs. The reborn conscious entity would start from the lowest root so that also it would experience childhood.

This option could solve the argued problems of the previous scenario and give concrete connection with the classical physics in accordance with QCC. On the other hand, a minimal modification of original scenario combined with $M^8 - H$ duality with moments $t = r_n$ as special moments in the life of conscious entity allows also to solve these problems if the active boundary of CD is interpreted as boundary beyond which classical signals cannot contribute to perceptions.

2.8.3 What could be the minimal modification of ZEO based view about consciousness?

What would be the minimal modification of the earlier picture? Could one *assume* that CDs serve as embedding space correlates for the perceptive field?

1. Zero energy states would be defined as before that is in terms of 3-surfaces at boundaries of CD: this would allow a realization of huge symmetries of WCW and the active boundary A of CD would define the boundary of the region from which self can receive classical information about environment. The passive boundary P of CD would define the boundary of the region providing classical information about the state of self. Also now BSR would mean death and reincarnation with an opposite arrow of time. Now however CD would shrink in BSR before starting to grow in opposite time direction. Conscious entity would have "childhood".

2. If the geometry of CD were fixed, the size scale of the $t = r_n$ balls of M^4 would first increase and then start to decrease and contract to a point eventually at the tip of CD. One must however remember that the size of $t = r_n$ planes increases all the time as also the size of CD in the sequences of SSRs. Moments $t = r_n$ could represent special moments in the life of conscious entity taking place in SSRs in which $t = r_n$ hyperplane emerges inside CD with increased size. The recent surprising findings challenging the Bohrian view about quantum jumps [L25] can be understood in this picture [L25].

3. $t = r_n$ planes could also serve as correlates for memories. As CD increases at active boundary new events as $t = r_n$ planes would take place and give rise to memories. The states at $t = r_n$ planes are analogous to seats of boundary conditions in strong holography and the states at these planes might change in state function reductions - this would conform with the observations that our memories are not absolute.

To sum up, the original view about ZEO seems to be essentially correct. The introduction of moments $t = r_n$ as special moments in the life of self looks highly attractive as also the possibility of wiping the slate clear by reduction of the size of CD in BSR.

3 Some comments related to Zero Energy Ontology (ZEO)

Zero energy ontology (ZEO) lies behind TGD based quantum measurement theory in turn giving rise to a theory of consciousness by making observed part of system as a conscious entity - self [L18]. ZEO solves the basic paradox of quantum measurement theory forcing to give up ontology altogether in the Copenhagen interpretation. ZEO has become a key aspect of the entire TGD based physics.

The basic prediction of ZEO is that ordinary ("big") state function reductions (BSFRs) involve change of the arrow of time. There is a lot of support for this prediction. The recent highly counterintuitive findings of Minev *et all* provided support for the time reversal in atomic systems [L25] [L25]. Fantappie [J2] proposed decades ago time reversal in living systems and introduced syntropy as time reversed entropy. In living matter the generation of more complex molecules from their building bricks can be seen as decay in time reversed direction. Phase conjugate laser beams are known to obey time reversed second law.

Also Libet's findings [J1] related to the active aspects of conscious experience find a nice explanation in terms of the time reversal. The latest application is to the understanding of the mysterious looking findings about earthquakes and volcanic eruptions suggesting that macroscopic quantum jumps involving time reversal are in question [L27]. This suggest that experimental verification of the time reversal and occurrence of macroscopic quantum jumps is possible by studying causal anomalies. For these reasons is important to try to develop the details of the view about ZEO as precise as possible.

In the sequel I will consider more precise mathematical formulation and physical interpretation of ZEO. ZEO forms also the cornerstone of TGD inspired theory of consciousness and quantum biology and I will consider also some related aspects of ZEO such as the notions of free will and intentionality, the notions of memory and precognition as its time reversal, intuitive in contrast to formal reasoning, and remote metabolism as a universal thermodynamical mechanism of metabolism in ZEO based thermodynamics.

3.1 General view about ZEO

The details of ZEO - in particular the technical details related to the conservation laws BSFR and SSFR - are from well-understood and the following is an attempt to fix these details by using analogy with cosmology.

3.1.1 Rough view about ZEO

Consider first what ZEO roughly means.

1. The realization of ZEO [L38, L18, L21, L34] involves besides the notions of "small" (SSFR) and "big" state function reduction (BSFR) also the notion of causal diamond (CD). CD

defines perceptive field of conscious entity as a 8-D region $cd \times CP_2$, where cd is the 4-D causal diamond of M^4 defined as the intersection of future and past directed light-cones.

2. At the classical level the basic entity is space-time surface connecting 3-surfaces at the opposite boundaries of CD. The space-time surfaces inside sub-CD continue outside and there is a hierarchy of CDs with largest CD beyond which space-time surfaces do not continue. This defines a space-time correlate for the hierarchy of selves.

   Space-time surfaces are preferred extremals of the basic action principle defined by the twistor lift of TGD [L24]. Minimal surfaces with 2-D string world sheets as singularities would be in question. They connect 3-surfaces at the boundaries of CD and are analogous to Bohr orbits so that not any pair is possible and the conditions characterizing preferred extremal property might even imply 1-1 correspondence between these 3-surfaces.

3. Zero energy states are superpositions of preferred extremals. One can also understand zero energy states as superpositions of deterministic programs - quantum programs, functions in the sense of quantum biology, or quantum behaviors. ZEO allows to solve the basic paradox of quantum measurement theory since the non-determinism of quantum jump between zero energy states corresponds to the causality of free will and is not in conflict with the classical determinism realizing the causality of field equations. Experienced time and geometric time are not same but there is a strong correlation between them.

4. In SSFRs the active boundary of CD shifts to future - at least in statistical sense. This is preceded by a unitary time evolution generating superposition of CDs with different sizes but having fixed passive boundary and same superposition of 3-surfaces at it. SSFR involves time-localization to single CD with fixed temporal distance between its tips. Essentially time measurement is in question.

5. In BSFR the arrow of time changes and one can say that state function reduction measuring set of observables takes place at the active boundary of CD, which becomes a passive boundary at which state does not change during subsequent SSFRs in which CD increases in opposite direction with the former passive boundary becoming an active boundary. The change of the arrow of time in BSFR creates the illusion that instantaneous quantum jump corresponds to a smooth and deterministic time evolution leading to the final state [L25] [L25].

The mathematical and physical details of the picture are not completely nailed down, and the best manner to proceed is to return to basic questions again and again and to challenge the details of the existing picture. In the following I will do my best to invent nasty arguments against ZEO.

3.1.2 ZEO and conservation laws

The geometry of CD breaks Poincare invariance. Lorentz invariance with respect to the either tip of CD is exact symmetry and is extremely attractive in the construction of members of state pairs in ZEO. Classically Poincare invariance is exact and one can deduce expressions for conserved quantities for both bosonic and fermionic sector: the latter have interpretation as operators, whose eigenvalues in Cartan algebra are by quantum classical correspondence (QCC) identified as classical values of conserved quantities.

ZEO involves the somewhat questionable assumption that one can assign well-defined Poincare quantum numbers to both boundaries and that these quantum numbers are opposite: this motivates the term ZEO.

1. M^8-H duality [L30] allows to assign to CDs with either boundary fixed a moduli space, which corresponds to Poincare group. The proposal is that Poincare invariance is realized at this level and that the values of conserved charges in Cartan algebra correspond to the Poincare quantum numbers labelling these wave functions. The wave functions at the boundaries of CD could be arranged in representations of Lorentz group acting as exact symmetry of the boundary.

2. There is further little nuisance involved. Only time translations, which correspond to a non-negative time value as distance from the fixed boundary of CD are possible. One would

obtain momentum eigenstates restricted to a future or past light-cone. This is of course what happens in TGD based cosmology. Maybe one must just accept this as a physical fact forcing to give up mathematical idealization.

Formally one would replace the plane wave basis with a basis multiplied by characteristic function for future or past light-cone equal to 1 inside the light-cone and vanishing elsewhere. This basis is closed with respect to summation. This would mean that the states are not anymore exact eigenstates of momentum globally but superposition of Lorentz boosts of the basic momentum obtained by Fourier expanding the characteristic function of future/past light-cone.

But what about CD which is intersection of future and past directed light-cones? Can one really assign to both boundaries wave functions defined in entire future (or past) directed light-cone? It seems that this is the case. Zero energy state would be entangled state as a superposition of products of boosted momentum eigenstates with opposite momenta representing the characteristic function of CD.

The usual idea about unitary time evolution for Schrödinger amplitude would be given up inside CD, and replaced by a sequence of unitary time evolutions producing de-localization of the active boundary of CD and followed by a localization.

3. There is still a problem. A complete de-localization for the boundaries of CD is not consistent with the intuitive idea that CD has definite size scale. In wave mechanics the plane waves are only idealizations and in the real world one replaces plane waves with wave packets. Gaussian wave packets have the nice feature that they remain Gaussian in Fourier transformation.

   If one has Gaussian wave packet for the temporal distance between the tips of CD concentrated on certain value of time, the Fourier transform for this is Gaussian wave packet concentrated around certain relative energy, which is two times the energy assignable to say passive boundary of CD. Instead of sharp value of time as distance between the tips of CD one would have Gaussian distribution for its value. This is consistent with Lorentz invariance since zero energy states allow superposition over states with varying momenta assignable to say active boundary. The wave function would be essentially Gaussian in energy in the rest system and one can consider also wave functions in Lorentz group leaving the passive boundary of CD invariant.

3.1.3 SSFRs in ZEO

In the proposed picture the sequence of SSFRs could mean gradual widening of the Gaussian wave packet for the value of measured time as the temporal distance between the tips of CD by discrete steps.

The basic condition is that the states at passive boundary of CD identified as superpositions of 3-surfaces remain unaffected during the sequences of SSFRs increasing the size of CD. This corresponds to generalized Zeno effect and in consciousness theory thr unchanging part of zero energy state corresponds to unchanging part of self, one might call it soul. One can imagine two options.

Option I: CD increases statistically in SSFRs but classical energy is conserved for space-time surfaces connecting its boundaries. Energy density would decreases as CD increases. This does not seem too bad actually: it would be analogous to matter dominated cosmology.

Not only superpositions of 3-surfaces at passive boundary of CD would be conserved but also their 4-D tangent spaces would be unaffected: this is unnecessarily strong a condition for generalized Zeno effect.

Option II: CD increases but classical energies decrease. This looks more plausible- if not the only - option and is strongly favoured by the analogy of CD with expanding cosmology. It also conforms with uncertainty principle. The process would be essentially quantum analog of cooling or analog for what happens for particle in a box expanding adiabatially. The classical energies of the space-time surfaces in zero energy state would thus decrease as CD increases.

Also this option allows the states as superpositions of 3-surfaces to at passive boundary of CD to remain unffected in expansion of CD. The classical energies can however decrease because the

space-time surfaces - tangent spaces of space-time surfaces at passive boundary - can change so that also energies can change.

This option is completely analogous to quantum adiabatic change in which the coefficients in the superposition of energy eigenstates are unaffected but energies change.

Option II looks more natural and will be considered in more detail.

1. The constraint that SSFRs as quantum measurements are for observables, which commute with observables, whose eigenstate the state at the passive boundary is, poses very strong constraints on what happens SSFR. Furthermore, preferred extremal is analog of Bohr orbit and cannot cannot be arbitrary pair of 3-surfaces. Therefore, when the CD changes, the preferred extremal also changes as a whole meaning also that also energy changes. These conditions could force adiabatic picture and the analog of Uncertainty Principle for classical energies as function of CD size.

2. The sequence of SSFRs could be also analogous analogous to what happens for a particle in box as the size of the box increases adiabatically: adiabaticity would actually be a hypothesis about what happens in the steps consisting of unitary evolution and SSFR. In adiabatic approximation the coefficients in the superposition of the energy eigenstates do not change at all: only the energies would change.

3. In thermodynamics this kind of process would correspond to a cooling, which could serve as a natural quantum correlate for the cooling in cosmology. In accordance with the idea that quantum TGD in ZEO corresponds to a complex square root of thermodynamics, one could interpret zero energy state as complex square root of thermal partition function for cosmology assignable to CD. The hierarchy of CDs would define Russian doll cosmology.

4. A further manner to understand this is in terms of Uncertainty Principle. As the size scale of CD given by temporal distance between its dips increases, the classical energy decreases. Intuitively the reduction of the classical energy is easy to understand. Increasing CD and keeping the 3-surface as such at passive boundary reduces time gradients at the passive boundary and space-time surface becomes more flat. Energy density is proportional to time gradients of coordinates and its therefore reduced. This argument is also used in inflation theories.

5. Change is the prerequisite of conscious experience and there would be indeed change also at the passive boundary of CD contributing to conscious experience. But in some sense this contribution - the "soul" - should *not* be changing! "Adiabaticity" would translate this idea to the language of physics.

What happens to CD in long run? There are two options.

1. The original assumption was that the location of formerly passive boundary is not changed. This would mean that the size of CD would increase steadily and the outcome would be eventually cosmology: this sounds counter-intuitive. Classically energy and other Poincare charges are conserved for single preferred extremal could fail in BSFRs due to the fact that zero energy states cannot be energy eigenstates.

2. The alternative view suggested strongly $M^8 - H$ duality [L11] is that the size of CD is reduced in BSFR so that the new active boundary can be rather near to the new passive boundary. One could say that the reincarnated self experiences childhood. In this case the size of CD can remain finite and its location in M^8 more or less fixed. One can say that the self associated with the CD is in a kind of Karma's cycle living its life again and again. Since the extension of rationals can change in BSFR and since the number of extensions larger than given extension is infinitely larger than those smaller than it, the dimension of extension identifiable in terms of effective Planck constant increases. Since $n = h_{eff}/h_0$ serves as a kind of IQ, one can say that the system becomes more intelligent.

   Also the temperature assignable to CD remains finite. In cosmological scales it could correspond to the analog of the temperature assignable to CMB. TGD based view about stars as blackhole like entities [L26] leads to the identification of the Hagedorn temperature assignable

to the volume filling flux tube giving rise to star with the Hawking temperature of dark radiation at gravitational flux tubes. Even CMB temperature could be assigned with dark photons at gravitational flux tubes. The asymptotic temperature for CD before BSFR could correspond to this temperature.

One expects that the center of mass coordinates of cm do not appreciably change during the quantum evolution. The hierarchy of CDs would imply that the Universe decomposes effectively to sub-Universes behaving to some degree independently. The view about Karma's cycles provides a more precise formulation of the pre-ZEO idea that systems are artists building themselves as 4-D sculptures. In particular, this applies to mental images in TGD based view about brain. The assumption that stars correspond to repeatedly re-incarnating conscious entities allows to solve several time anomalies in cosmology [L26] so that there would be a direct connection between cosmology and theory of consciousness.

There could be a relationship between quantal flow of geometric time by SSFRs and p-adic variant of time coordinates giving a reason why for p-adicity.

1. TGD predicts geometric time as a real variant and p-adic variants in extensions of various p-adics induced by given extension of rationals (adelic space-time and adelic geometric time). Real and p-adic times share discrete points in the extension of rationals considered: roots of octonionic polynomials defining space-time surfaces as roots for their "real" and "imaginary" parts in quaternionic sense [L28]. The roots of the real polynomial with rational coefficients giving octonionic polynomial as its continuation define space moments of M^4 linear time assignable to special SSFRs. p-Adic time associated with the p-adic balls assignable the points are not well-ordered. One cannot tell about two moments of time which is earlier and which later.

2. This could relate to the corresponding lack of well ordering related to "clock time" associated with self at given level of evolutionary hierarchy defined by the extension of rationals. The increase of "clock time" as a distance between tips of CD for a sequence of small state function reductions (weak measurements) occurs only in statistical sense and "clock time" can also decrease. The moments of time correspond to roots of the real polynomial define "special moments in the life of self", one might say.

   At the limit of infinite-D extension the roots of the polynomial define algebraic numbers forming a dense set in the set of reals. Cognitive representation becomes dense set. These "special moments" need not however become dense.

3. One can raise an interesting question inspired by self inspection. As one types text, it often happen that the letters of the word become in wrong order, change places, and even jump from a word to another one. The experienced order of letters assignable to a sequence of SSFRs is not the same as the order of letters representing the order for the moments of geometric time. When one is tired, the phenomenon is enhanced.

   Neuroscientists can certainly propose an explanation for this. But could this be at deeper level quantum effect based on the above mechanism and have a description in terms of p-adicity assignable to prime p defining a ramified prime for the extension of rationals involved? When one is tired the metabolic resources have petered out and the IQs $n = h_{eff}/h_0$ defined by dimensions of extensions of rationals for the distribution of extensions tend to reduce, cognitive resolution for time becomes lower and mistakes of this kind become worse.

There is a further technical detail involved. For SSFRs the temporal distance between active boundary and passive boundary increases at least in statistical sense. It seems that one must define the inner product in S-matrix elements for the unitary step preceding SSFR using the previous state basis as sub-basis of the new state basis in the case that CD increases. In adiabatic approximation the S-matrix elements would be overlaps for the states with different size of CD and analogous to matrix elements between states of particle in boxes with the same fixed end but different moving end.

3.1.4 BSFRs in ZEO

Details of BSFR are not completely fixed. One can consider two options. Both options must satisfy the condition that the states at passive boundary of CD identified as superpositions of 3-surfaces remain invariant during the sequence of SSFRs. The tangent space-to the space-time surfaces need not however remain invariant. Therefore the classical energies of space-time surfaces can change since the energy densities are proportional to time derivatives of embedding space coordinates.

1. The size of CD increases steadily as was the original proposal and is thus not reduce in BSFRs. The problem with the steady increase seems to be that the size of CD becomes infinite eventually and the state evolves to what looks like cosmology. If the energy assignable with zero energy state is conserved, the energy density of matter inside CD increasing without limit becomes arbitrarily small. Is this a catastrophe?

   For TGD inspired cosmology this is the case at the limit of big bang in the sense that the energy density goes like $1/a^2$ (cosmic string dominance) and energy in a co-moving volume vanishes like a, where a is light-cone proper time. One can think that CD defines only perceptive field and that space-time surfaces continue also outside CD up to the maximal size of CD in the hierarchy of selves involved. The zero energy state would have finite energy energy but density of energy would go to zero at the boundary of CD. The perceptive field of conscious entity would increase steadily in size.

   As found, energy need not be conserved in the subsequence SSFRs because Gaussian wave packets of CDs around given size are required so that eigenstates of energy are not in question and the reduction of the width of Gaussian in the sequence of SSFRs implies reduction of average energy. Only the superpositions of 3-surfaces at the passive boundary of CD would be conserved.

   Even the conservation of energy combined with the increase of CD need not be a catastrophe. In matter dominated cosmology the conservation of mass takes place with respect to cosmological time which corresponds to the proper time measured as temporal distance from the passive tip of CD. This cosmological mass is not energy but closely relates to it. What looks of course counter-intuitive is that every self would evolve to a cosmology.

2. The size of CD could be also reduced in BFSR [L28]. $M^8 - H$ duality and existence of "braney" solutions encourages to take this option serious. The 6-D brane like entities correspond to $t = constant$ sections for linear M^4 time t. They would represent special moments in the life of self. The exceptional 6-D roots of octonionic polynomials as branes would emerge to the perceptive field conscious entity at these moment. Discontinuity of classical space-time evolution as SSFR. Every time-reversed re-incarnation of self would have have "childhood" and experience increase of CD from some minimal size to maximal size.

   Since the size of CD can be reduced, it could happen that the CD remains stuck below certain maximal size for ever. The associated mental images would continue living in the geometric past of bigger CD associated with self. The sub-CDs in past would represent memories of self. Cosmos in 4-D sense would be full of life. The interpretation of CD as perceptive field allows this. CD could also increase and become even a cosmology! This picture looks attractive from the view point of consciousness.

3. One can however invent an objection against ZEO, one might even speak about paradox.

   (a) Suppose that in biological death I indeed re-incarnate with opposite arrow of time and continue to live towards geometric past. Suppose also that I re-incarnate as more advanced human being - at least in statistical sense. Human beings have parents. But how can I have parents in the former geometric future, if my parents how have already died live in the former geometric past?

   (b) The only solution of the paradox seems to be that the magnetic body (MB) - the boss - does not disappear in the death of biological body (BB). The MBs of my parents continue their existence and in my biological death means their separation in stanard time direction and meeting in the new time direction. They meet, fall in love, and give rise to my birth but all this in opposite time direction.

This would provide an answer to a long-standing question about whether MBs are preserved in biological death or not. My view has been that biological death is more or less that MB loses interest in my BB and directs attention to something more interesting. One could however argue that also MB is generated in birth and genes code also for it so that it would die. If directing attention corresponds to BSFR MB would continue to exist after biological death. This particular reincarnation - CD - would be like vortex in the flow of time.

(c) Can one find any support for this crazy looking proposal? TGD Universe is fractal and lower levels in the length scale hierarchies are slaves. In particular, bio-chemical level serves as the slave of MB expected to obey kind of shadow dynamics. If the proposed topological dynamics of MBs solving the above paradox has a miniature representation at the level of DNA, one could take the proposal with some seriousness.

In meiosis (`http://tinyurl.com/n5eqkdn`) germ cells, whose chromosomes are coctails of paternal and maternal chromoses (PCs and MCs), are formed. In fertilization (`http://tinyurl.com/ngzwhcq`) - in some sense a (time?) reversal of meiosis - pairs of PCs and MCs are formed. The fusion of paternal and maternal germ cells could be indeed seen in topological sense as a time reversal of replication. The replication of soma cells involves mitosis (`http://tinyurl.com/p35lkwr`) forming pairs of chromosomes of PCs and MCs.

Could the chromosomal dynamics be a miniature version of the proposed dynamics at the level of MB even at the level of organisms? If so, mitosis at the level of MB would correspond to a loose pairing of paternal and maternal MBs - formation of a relationship. Our personal MBs as analogs of germ cells would be coctails of MBs of PCs and MCs formed by reconnection process.

What about replication? In the case of asexual reproduction (`http://tinyurl.com/y8odomtf`) one could speak about replication at the level of MB of the entire organism. Also cell - and DNA replication would represent examples of asexual reproduction and in meiosis sexual reproduction of also DNA would take place.

When does BSFR occur? I have imagined several options, which need not exclude each other.

1. Could BSFR occur, when there are no observables at the active boundary commuting with those diagonalized at passive boundary. Measurement of observable at means generation of eigenstate in the extension of rationals and it typically occurs that the resulting state is outside the extension. Could BSFR occur when there are no observables in the extension of rationals in question.

2. $M^8 - H$ duality predicts universal special solutions besides 4-D space-time surfaces. These 6-D analogs of branes correspond to n moments of linear M^4 time, where n is the polynomial whose octonionic continuation defines space-time surfaces in M^4 as roots of its real or imaginary part in quaternionic sense. At these branes 4-D space-time surfaces are glued together along their ends- space-time looks is analogous to piecewise continuous curve in time direction - and they would correspond to "special moments in the life of self" [L28]. When all these moments as special roots of the octonionic polynomial are experienced, BSFR would be the only possibility. The polynomial with rationals coefficients defining the octonionic polynomial defines the extension of rationals used so that this option could be consistent with the first option.

3. Is BSFR is forced to occur because there are no preferred extremals connecting the pairs of 3-surfaces exists anymore. Could it happen that the state becomes increasingly classical during the sequence of SSFRs and thus becoming more and more local in WCW (the "world of classical worlds", which is essentially the space of 3-surfaces at either boundary of CD). The unchanging part of the zero energy state associated with the time-reversed state as outcome of BSFR at the new passive boundary would be maximally classical. This might relate to the fact that the world looks so classical. Also the fact BSFRs themselves look classical smooth time evolution ending to the outcome of BSFR, creates the illusion of classicality [L25].

3.2 ZEO, life, and consciousness

The most important implications of ZEO relate to consciousness and quantum biology. One can understand act of free will and motor action in terms of BSFR. BSFR corresponds to motor action and its time-reversal. SSFRs correspond to sensory perception in either direction of time [L23]. Model for memory is one prediction and predicts precognition as time reversal of memory [K20] [L40]. Also the relationship between generation of insight and mechanical logic deductions can be understood. In biology ZEO leads to remote metabolism as a universal purely thermodynamical mechanism of metabolism. One can also understand zero energy states as superpositions of deterministic programs - quantum programs, functions in the sense of quantum biology, or quantum behaviors.

3.2.1 Act of free will, intentionality, and ZEO

Act of free will would correspond to BSFR that is quantum jump leading to final state with opposite arrow of time. Final state is a superposition of deterministic time evolution connecting the 3-surfaces in the superpositions defining initial and the final states. In this picture state function reduction leads to final state inducing time reversed time evolution so that classically the causal order is changed. What in standard picture - say neural activities - causes the outcome, is caused by the outcome. Could it be that mere volitional act with sharp enough intention is needed? The correct deterministic time evolution is dictated by intention as consequence rather than cause!

Here I cannot avoid the temptation to tell about my own strange experiences. At this age one must remember to take the pills every morning. I have the habit of filling my pill dispenser every Monday morning. I do not bother to count the pills one by one. I just take randomly a bunch of them hoping that their number is correct. And it is! Quite too often! Similar thing happens in market when I pay with coins: I do not count the coins but just take a handful of them. The sum of the coins is correct quite too often! Could a mere sharp intention dictate the outcome. Could one learn gradually this kind of sharp intentions.

Could this be crucial for various skills like playing tennis or computer game, where one simply cannot react rapidly by computing the outcome since time does not allow it? Could this explain also mathematical/physical/.. intuition as skill to solve problems by making quantum jump directly to the solution of the problem.

3.2.2 Precognition and ZEO

It seems that neuroscientists are beginning to take remote mental interactions such as precognition, telepathy, and psychokinesis seriously. The popular article entitled "*Scientists Discover That The Heart & Brain Respond To Future Events – Before They Happen*" (see `http://preview.tinyurl.com/y494hw5u`) describes changing views of neuroscientists towards precognition.

In ZEO precognitions are naturally time-reversed memories. Classical signals giving rise to sensory experience arrive from geometry future in the standard frame. During sleep state precognition should be possible if sleep corresponds to time-reversed state for the self.

In the associative and computational models of brain our ability to predict the future is taken to be an extrapolation based on memories and experience of earlier life. This looks very reasonable but when one asks how these memories are represented, problems begin to appear. In TGD framework ZEO predicts that memories correspond to mental images in geometric past, in the simplest case, when the original event took place. This solves a huge problem of standard since memory storage becomes brain in 4-D sense rather than in 3-D sense [K20].

ZEO however implies that also time reversed memories are possible. If sleep state correspond to time reversed self about which we do not have direct memories, memories with reversed arrow of time would be possible in this state. Precognition becomes possible if these memories can be communicated to the wake-up state with the ordinary arrow of time. In dreams some parts of brain are awake and they could make possible this communication. The communicated information could be also conscious to some selves above or below us in the hierarchy. Dreams can indeed predict what happens during the next day. The classical book "*An Experiment with Time* " (see `http://tinyurl.com/jtqysty`) of J. W. Dunne tells about precognitive dreams that he experienced.

3.2.3 Intuitive and formal logical reasoning in ZEO

The basic vision is that adelic space-time geometry provides correlates for sensory experience and cognition/imagination. Fermionic degrees of freedom would represent quantal Boolean mind. In ZEO given deterministic time evolution for 3-surface and induced spinor fields would give rise to sensory and cognitive time evolution and to Boolean evolution having interpretation as analog of logical deduction leading from premises to conclusions.

1. The basis of fermionic Fock states can be regarded as Boolean algebra. Superpositions and thus entanglement of fermionic qubits are however possible and one can speak about quantum Boolean logic. In standard view concepts are formally regarded as sets containing the instances of concept as elements. Quantum concepts could be superposition of quantum states representing the instances so that quantum abstraction would be much more complex notion than ordinary abstraction. Non-classical Boolean states would be superpositions of statements identifiable as abstractions. Schrödinger cat would be seen abstraction. "Dead" and "alive" would represent instances of this abstraction.

2. Zero energy states are superpositions of initial and final fermion states and there is also a superposition over 3-surfaces, and could be interpreted as representations for implications. The sum $\sum_n S_{mn}|n\rangle$, where S denotes unitary S-matrix, represents a superposition over all transitions $|m\rangle \to |n\rangle$ allowed by laws of physics. These transitions could be interpreted as logical implications.

   One could argue that by diagonalizing S-matrix one obtains only diagonal transitions and the situation is rather trivial: just logical identities. The point is however that in number theoretical physics the diagonalization of S would in general lead outside the extension of rationals determining the adele and is therefore not possible. Same number theoretical mechanism would also stabilize negentropic entanglement and could force BSFR. Only state big state function reduction extending the extension of rationals can reduce this kind of entanglement.

3. Probably every mathematician has pondered the mystery of mathematical insight. How for instance mathematical insight is generated? What eureka experience is basically? Insight would correspond naturally to a big state function reduction leading to a new state reversing the arrow of time.

   Truth can be deduced in given system of axioms also mechanically - at least in principle. How does insight relate to a logical deduction leading to a theorem? The final state of quantum jump is superposition of classical time evolutions leading from the final state to geometric past. With respect to standard arrow of time it is superposition of logical deductions leading from various initial states- initial assumptions - to the final state - to the outcome of the deduction. Superposition of states at boundary of CD could be seen as an abstraction. Deterministic time evolutions would represent the mechanical deductions.

   Note however that in the time reversed state arbitrary long time evolution in opposite time direction is in principle possible and would correspond to an arbitrary long ordinary deduction or computation [L8]. After that a return to the original arrow of time would take place and provide the solution. The formal deduction leading to the outcome would be indeed forced by the outcome rather than vice versa?

3.2.4 Metabolism in ZEO

ZEO has also deep implications for biology. As already explained, ZEO allows to understand what behaviors, biological functions are at fundamental level.

Why metabolism is needed can be understood in TGD view about dark matter as phases of ordinary matter labelled by the value of effective Planck constant $h_{eff} = n \times h_0$, where n has also interpretation as dimension of extension of rationals giving rise to the extension of adeles [L16, L17]. n serves as a kind of IQ labelling different evolutionary levels and is bound to increase in statistical sense. Not only biology but also self-organization involving also energy feed could be understand in terms of the hierarchy of Planck constant.

In ZEO remote metabolism suggests itself as a completely universal purely thermodynamical mechanism of metabolism. Usually system loses its energy by dissipation. If the arrow of time

is non-standard, systems seems to receive energy from environment. Note that the duration of time spent in time reversed state does not matter! What matters is the increment of time between states with same arrow of time! Sleep state could be seen also as a way to collect metabolic energy. BSFR can be seen as an act of free will - motor action and sucking of metabolic energy from "environment" would be very natural.

The interpretation for the return to the original time direction by second BSFR would be as beginning of sensory perceptions in standard arrow of time as sequences of SSFRs. During this period subsystem would be dissipating energy to environment.

3.3 Under what conditions does BSFR take place and what happens in it?

In the following the question under what conditions "Big" state function reduction (BSFR) takes place and what happens in it.

3.3.1 Two kinds of state function reductions

The discussion however requires the basic ideas of ZEO as background.

1. "Small" state function reductions (SSFRs)

Small state function reductions (SSFRs) are counterparts of so called "weak measurements", which are rather near to classical measurements in the sense that nothing drastic happens.

1. The passive boundary of CD does not shift but changes in size because active boundary shifts and this induces change of size. For state pairs defining zero energy states the members at passive boundary do not change and the coefficients of possibly time-entangled state defined as their superposition do not change. The members of state pairs at active boundary change and this change is induced by unitary time evolution between too SSFRs. This time evolution could be regarded as a generalization of adiabatic time evolution.

2. In statistical sense the active boundary shifts towards future and the size of CD increases. The temporal distance between the tips defines clock time in one-one correspondence with SSFRs. Note that the unitary evolution forms a superposition of CDs with different sizes and SSFR means localization to single CD size.

3. The moment "Now" of self would naturally correspond to the M^4 hyper-plane dividing CD into two pieces of identical size. The radius of this 3-ball would be $r = T/2$, where T is the temporal distance between the tips of CD. At this hyperplane expansion of 3-ball with light-velocity would transform to contraction.

4. The mental images of self would correspond sub-CDs and also they would shifts towards geometric future in the sequence SSFRs. They would form a kind of log file about the life history of self such that geometric time order would be opposite to subjective time order. Self could remember these experiences by sending signals to geometric future reflecting back in time direction - seeing in time direction would be in question.

   What is in sharp conflict with natural expectation is that the memories would be stored in geometric future and part of them would become un-changing permanent part for the time reversed re-incarnation of self- kind of Karma.

   Note however that self might have also mental images represented as sub-CDs in geometric past.

$M^8 - H$-duality suggests space-time picture about the "log files".

1. 4-D space-time surfaces in complexified M^8 having interpretation as complexified octonions are 4-D roots for octonion valued polynomial obtained as an algebraic continuation of a real polynomial with rational or even algebraic coefficients. $M^8 - H$ correspondence maps thee surfaces to minimal surfaces with 2-D singularities in H [L30, L28].

2. Besides this one obtains for any polynomial also special solutions as analogs of branes in M-theory. They have topology of 6-D ball and their projection to M^4 is $t = r_n$ hyperplane intersecting CD and with topology of 3-ball. r_n is a root of P and thus an algebraic number. I have called $t = r_n$ "very special moments in the life of self". Generalized vertices for particle reactions would correspond to partonic 2-surfaces localized at these 6-surfaces. At these surfaces incoming and outgoing partonic orbits would be glued together along their ends. The roots define positions of external particles at the boundaries of CD.

3. In SSFRs these balls at the active half of CD would shift towards future and new roots would emerge. These roots wold define a geometric representation of the memories of CD as "log file" increasing in size. If there are sub-CDs associate with them, one would have mental images shifting towards future.

2. "Big" state function reductions (BSFRs)

"Big" state function reductions (BSFRs) correspond to ordinary state function reductions (SFRs) in ZEO. In BSFR the roles of active and passive boundaries of CD are changed and the arrow of geometric time changes since the formerly passive boundary starts to shift to opposite time direction. State function reduction not commuting with the observables defining states at passive boundary as their eigenstates would takes place and the state at passive boundary would be changed. It would be however fixed by quantum dynamics. The findings of Minev *et al* provide support for the change of the arrow of time in ordinary SFR [L25].

The passive boundary can be shifted towards future so that the size of CD would decrease. One can say that the re-incarnate would be experience childhood. Note that also part of the "log file" about often personal experiences of self towards end of its life defining the permanent part of self-hood of the re-incarnate would disappear. The interpretation in terms of Karma is suggestive.

Remark: During a discussion with Marko Manninen, Marko noticed that people who have had near death experience often report that they experienced their entire life like a film during these moments. Could the "log file" representing stored mental images give rise to this experience at the moment of death?

3.3.2 What happens in biological death from TGD perspective?

What happens in biological death can be taken as a guideline in attempts to understand what happens in BSFR.

1. Death certainly occurs if there is no metabolic energy feed to the system. Metabolic energy feed is guaranteed by nutrition using basic molecules as metabolites. Since the increase of h_{eff} quite generally requires energy if other parameters are kept constant and since the reduction of h_{eff} can take spontaneously, the metabolic energy is needed to keep the distribution of values of h_{eff} stationary or even increase it - at least during the growth of organism and perhaps also during the mature age when it would go to increase of h_{eff} at MB.

   If the size of CD for at least MB correlates with the maximum value of h_{eff} or its average, the size of CD cannot grow and can be even reduced if the metabolic energy feed is too low. The starving organism withers and its mental abilities are reduced. This could correspond to the reduction of maximum/average value of h_{eff} and also size of CD.

   One can argue that if the organism loses metabolic energy feed or is not able to utilize the metabolic energy death and therefore also BSFR must take place.

2. In ZEO self-organization reduces to the second law in reversed direction of geometric time at the level of MB inducing effective change of arrow of time at the level of biological body [L31]. The necessary energy feed correspond to dissipation of energy in opposite time direction. In biological matter energy feed means its extraction from the metabolites fed to the system. One could say that system sends negative energy to the systems able to receive it. A more precise statement is that time reversed subs-system dissipates and metabolites receive the energy but in reversed time direction.

   In living matter sub-systems with non-standard arrow of time are necessary since their dissipation is needed to extract metabolic energy. The highest level dissipates in standard time

direction and there must be a transfer of energy between different levels. This hierarchy of levels with opposite arrows of geometric time would be realized at the level of MB.

3.3.3 Death as a re-incarnation with opposite arrow of time

These observations suggest that one should consider the reincarnation with opposite arrow of time with wisdom coming from the death of biological systems.

1. We know what happens in death and birth in biological systems. What happens in biological death should have analogy at general level. In particular, in death the decay of the system to components should occur. Also the opposite of this process with reversed arrow of time should take place and lead at molecular level to the replication of DNA and RNA and build-up of basic biomolecules and at the cell level to cell replications and development of organs. How these processes could correspond to each other?

2. The perceived time corresponds to the hyperplane $t = T/2$ dividing CD to parts of same size. Here T is the distance between the tips of CD and therefore to maximal diameter of temporal slice of cd, which is 3-ball. The part of CD above it shifts towards future in SSFRs. In BSFR parts of the boundary of space-time surfaces at the active boundary of CD become unchanging permanent parts of the re-incarnate - kind of log file about the previous life. One can say that the law of Karma is realized.

   If CD decreases in size in BSFR the former active boundary keeps its position but its size as distance between its tips is scaled down: $T \to T_1 \leq T$. The re-incarnate would start from childhood at $T - T_1/2$ and would get partially rid of the permanent part of unchanging self-hood corresponding to interval $[T - T_1/2, T/2]$ so that the permanent part of reincarnate would correspond to $[T - T_1/2, T]$. Reincarnate would start almost from scratch, so to say. The part between $T - T_1/2$ and T would be preserved as analog of what was called BIOS in personal computers.

3. At the moment of birth CD possibly would thus decrease in size and the former passive boundary now in the range $[T - T_1/2, T - T_1]$ and lower tip of new CD at $T - T_1$ would become active and the seat of sensory experience. Arrow of time would change. Where the analog of biological decay is located? The region of CD in the range $[T/2, T - T_1/2]$ disappearing from "log file" is the natural candidate. This region is also the place, where the events related to birth in opposite time direction should take place.

4. The decay of the organism should therefore correspond to the development and birth of re-incarnated organism at the level of MB (it must be also remembered that genuine time reversal takes place at the level of MB and induces only effective time reversal at the level of ordinary bio-matter). The decay of organism dissipates energy in standard time direction: this energy could used by the re-incarnate as metabolic energy. How long lasting biochemical processes have effective time reversals depends on the quantum coherence scale determined by the size scale of corresponding CD.

3.3.4 Could the re-incarnations with opposite arrow of time be seen in bio-chemistry?

The possible occurrence of effective time reversals at the level of bio-chemistry could be perhaps tested experimentally.

1. Could the replication of DNA and RNA and build-up of various bio-molecules be effective time-reversals for their decays. Could the same apply to the replication of cells and generation of organs. Replication of DNA is self-organization process in which second DNA strand serves as a template for a new one. The decay of DNA should therefore involve two DNA strands such that the second DNA strand serves as a template for the effectively time reversed replication. The double strand structure indeed makes possible for the other strand to decay first. Cell replication should use another cell as replicate and same would happen in the cell decay.

2. An interesting mental exercise is to imagine the time reversals of various basic processes like transcription and translation. In the time reversal of translation of mRNA to amino-acid sequence the amino-acid sequence and mRNA would return to ribosome machinery, and amino-acid and tRNA codon associated with tRNA would return to form tRNA. mRNA strand would shift one step backwards and the process would repeat itself and finally mRNA strand would return to open DNA strand. In the time reversal of transcription of DNA to mRNA, mRNA strand would return to open part of DNA strand, decay to RNA codons and eventually DNA strand would close. It should be easy to check whether these processes really occur in the decay process.

3. The formation of stem cells involves de-differentiation. Could it mean time reversal of the entire process leading to a differentiated cell? Also this idea could be tested.

In biology pairs of various structures often occur. Could they correspond in some sense to effective time reversals of each other whereas at the level of magnetic body one would have genuine time reversals

1. Could the opposite inherent chiralities of MBs of DNA strands correspond to opposite arrows of time at the level of MB of DNA realizing dark genetic code [L6]? Could this be seen as a kind of explanation for the double strand structure of DNA. Could the passivity of DNA strand with respect to transcription correspond to opposite arrow of time at the level of MB? Could the passive strand become active in time reversal?

2. Even brain has this kind of pairing. Right brain hemisphere is passive in the sense that it does not seem to contribute to wake-up intelligence (presumably identified as analytic intelligence). Could either hemisphere serve as a template in the development of brain or could this happen only at the level of MB of brain? Could different time arrows at the level of MB be used to understand the strange passive character of right brain and could one one understand the holism of right brain *viz.* analytic reductionism of left brain as reflection of the fact that dissipation as decay corresponds to time reversal for self-organization generating structures at the level of MB.

3.3.5 What about ordinary re-incarnation?

A couple of comments relating to the notion of re-incarnation in standard sense are in order.

1. Eastern philosophies talk about the possibility of liberation from Karma's cycle. Can one imagine something like this? The above picture would suggest that in this kind of process the reduction of the size of CD does not occur at all and therefore there would be no decay process equivalent to the growth of time reversed organism. This would serve as an empirical signature for the liberation - if possible at all. CD would continue to increase in size or perhaps keep its size. It would seem that a new kind of non-biological source of metabolic energy would be needed.

2. Reincarnation is a basic notion in Eastern philosophies. In ordinary reincarnation person has memories about life of a person, who lived earlier. There is evidence for this. This cannot be understood in terms of time reversed re-incarnation.

   Recall that there would be a hierarchy of selves and corresponding CDs within CDs. It has remained an open question whether CDs could also overlap? Could re-incarnation in ordinary sense be explained in terms of this kind of overlap?

   Suppose that one has two overlapping CDs: CD_1 and CD_2 and that CD_2 extends farther to the future of CD_1. The sub-CDs of CD_1 shift to future as the active part of CD_1 shifts to future and increases in size giving rise to a kind of log file defining the personal memories of CD_1. In this kind of situation the mental images of CD_1 can enter to CD_2 and become mental images of CD_2. This would be sharing of mental images but in different sense as compared to the fusion of mental images by entanglement, which could also require intersection of sub-CDs of mental images.

Could one imagine that the cosmos is full of selves serving as counterparts of memes wandering around and finding for selves hosting them by providing metabolic energy? Note that ZEO means that CD center of mass degrees of freedom do not carry any conserved quantum numbers so that the motion of these lonely CDs would not be restricted by conservation laws!

3. This picture suggests that CD:s form a conscious fractal atlas consisting of charts with various resolutions analogous to the atlas defining a covering of manifold by open sets. The earlier proposal was that in biological death MB redirects its attention to a new system. This picture would be modified: the MB of of CD_1 would still attend the time-reversed system and experience time-reversed life. Some sub-CDs of CD_1 would however belong to a new CD in its geometric future - CD_2. This conforms with the intuitive expectation that space-time surfaces continue outside CD and only the perceptive field of conscious entity is restricted to CD.

4. Mental images should correspond to sub-selves and therefore sub-CDs of CD. Contrary to what I have proposed earlier, it seems that after images cannot correspond to BSFR type re-incarnations of mental images nor re-incarnations in standard sense.

   Mental images would shift towards the future together with active part of CD and form a kind of log file. Could after images be memories of previous mental images involving a signal time reflect from the the mental image in log file and creating the after image as a sensory memory of the earlier visual mental image? Or could one understand after images in terms of propagation of dark photon signals along closed magnetic loops giving rise to periodically occurring mental images.

In [L43] I discussed how the evolution of self by BSFRs could correspond to a transition to chaos as iteration of the polynomial defining the space-time surface. The proposed picture was that the evolution by SSFRs corresponds to iteration of a polynomial P assignable to the active boundary of CD. This would predict a continual increase of the degree of the polynomial involved. This is however only one possibility to interpret the evolution of self as iteration leading to chaos.

1. One could argue that the polynomial $P_{nk} = P_n \circ .... \circ P_n$ associated with the active boundary remains the same during SSFRs as long as possible. This because the increase of degree from nk to $n(k+1)$ in $P_{nk} \to P_{nk} \circ P_n$ increases h_{eff} by factor $(k+1)/k$ so that the metabolic feed needed to preserve the value of h_{eff} increases.

   Rather, when all roots of the polynomials P assignable to the active boundary of CD are revealed in the gradual increase of CD preserving P_{nk}, the transition $P_{nk} \to P_{nk} \circ P_n$ could occur provided the metabolic resources allow this. Otherwise BSFR occurs and self dies and re-incarnates. The idea that BSFR occurs when metabolic resources are not available is very natural for this option.

2. Could $P_{nk} \to P_{nk} \circ P_n$occur only in BSFRs so that the degree n of P would be preserved during single life cycle of self - that n can increase only in BSFRs was indeed the original guess.

While preparing this contribution I learned about a highly interesting claim (`https://tinyurl.com/yap8ss4p`) made by the research group led by Harold Katcher. The claim is that the epigenetic age (there are several measures for it such as methylation level of DNA) of rats has been reduced up to 50 percent. The theory goes that epigenetic age of molecules would be controllable by hormonal signalling globally.

BSFR would mean death of conscious entity and its reincarnation with opposite arrow of time. The system would rejuvenate in the transition starting a new life in opposite time direction from childhood so to say - rejuvenation would be in question. Doing this twice would lead to life with original arrow of time but starting in rejuvenated state. The claim of the group suggests that living matter could do this systematically using hormonal control.

3.3.6 Tukdam and TGD

This piece of text was inspired by a document (`https://rb.gy/abt8za`) about a strange phenomenon known as Tukdam. What happens is that in Tukdam the person is physically dead but is believe to be in a continued meditation. There is no EEG, the heart does not beat, and there is no normal metabolism. However, the decomposition processes do not start. The condition can last up to a couple of weeks. Similar longer-lasting ones have been reported: a yogi can be buried underground for months in an oxygen-free state and then wake up.

This challenges neuroscience's view of the brain as the seat of consciousness. According to reports there could be awareness and a sensory experience consisting of different light sensations. The Tibetan Book of the Dead describes these experiences. Near-death experiences have many similar features [L48].

In the body in Tukdam, the area of the heart is reported to feel warmer to the touch than the rest of the body, but the thermometer does not detect this difference. This would indicate that the body receives metabolic energy at the cellular level from some other source than in the normal metabolism, and that living matter can detect what measuring devices based on the recent knowledge provided by modern physics cannot detect. Where could this energy come from? If one wants to answer this, one must also ask what happens in death and what is consciousness and what is life.

1. Dark energy and matter are the two basic puzzles of recent day physics. In the TGD approach, I have identified dark matter as a phase of ordinary matter, for which the effective Planck constant h_{eff} is much larger than normally.

   In particular, the gravitational Planck constant $h_{eff} = h_{gr}$ assignable to gravitational flux tubes can be very large and makes quantum coherence possible even on astrophysical scales. Large Planck constants would be associated with the dark matter magnetic body, which would be the TGD counterpart to the magnetic field of Maxwell's theory, but would differ from it in many respects. As a quantum coherent unit, this magnetic body would control the ordinary biological body and induce its coherence. The classical energy of a magnetic body, consisting of volume energy and magnetic energy, would be dark energy.

2. In the TGD Universe dominated by zero energy ontology, consciousness is a universal phenomenon and present on all scales, from elementary particles to the level of the cosmos. Even galaxies, stars and planets would be conscious beings. Also life and death would be universal phenomena. Likewise, the biological decomposition process associated with death would correspond to the universal decomposition process, which would essentially correspond to the decomposition of magnetic monopole flux tubes (magnetic catabolism), which would induce the catabolism of the breakdown of biomolecules. Its time-reversed version would be magnetic anabolism and induce the building of bio-structures such as molecules.

3. The fundamental metabolic processes would be essentially magnetic anabolism and catabolism induced by "big" state function reductions (BSFRs) changing the arrow of time and inducing the biological anabolism and catabolism. Death would mean reincarnation with the opposite arrow of time.

In Tukdam, the biological body would be dead, but the magnetic body would still be alive and prevent the biological decay from starting. The disintegration of the magnetic body would start in Tukdam much later than normally, and initiate the disintegration of the biological body. The content of the conscious experience in Tukdam, light sensations and deep peace, would come from the magnetic body. The dead biological body would not provide contribution from sensory input, motor activity, and cognition.

By a strange accident, just before seeing the document about Tukdam, I wrote an article [L56, L58] about a seemingly completely unrelated topic, solar flares related to the reversal of the direction of the sun's magnetic field in the solar cycle, which has a period of 11+11 years.

The reversal of the Sun's magnetic field would correspond to magnetic catabolism as the breakdown of long monopole flux tubes into very short parts. It would be followed by magnetic anabolism as their re-fusion into long flux tubes. The solar cycle would correspond to the sleep-wake cycle,

or more precisely: a series of lives in different directions of time. Death would only be a change of time's arrow, nothing final.

The model unexpectedly leads to a biological analogy and to understanding what might happen to the magnetic body in biological death.

3.4 Conditions on the periods with reversed arrow of time

In zero energy ontology (ZEO) falling asleep (death at"my" level of self the hierarchy) corresponds to ordinary - or "big" - state function reduction (BSFR) and also means a reincarnation with opposite arrow of time. We would be therefore conscious during sleep and wake-up would correspond to falling sleep of that other, time reversed self.

When I fall asleep, I wake-up later tomorrow morning for instance, not yesterday morning. It is interesting to see what kind of conditions this implies and whether it is possible to satisfy this easily and even more interesting is to see whether a time travel to the geometric past - maybe the Golden Youth - could be possible.

The following assumptions are made about what happens in BSFR.

1. Causal diamond (CD) is a correlate for self. CD is obtained by gluing together two identical half-cones along their bottoms. Moment "Now" corresponds to the largest hyperplane $T_{now} = T$ (origin of time coordinate is at either (call it "lower") tip of CD) .

2. During the sequence of SSFRs defining self, the 3-surfaces at the passive boundary of self are fixed although their 4-D tangent space changes and corresponds to the unchanging part of selfhood - soul one might say. The opposite active boundary of CD and 3-surfaces at it change and shift towards geometric future.This gives rise to wake-up consciousness involving sensory input and thoughts, emotions etc. induced by it. Each SSFR is preceded by the analog of unitary time evolution.

3. BSFR means a death of self (subself) and its reincarnation with an opposite arrow of time. One can equally well speak about the analog of falling in sleep and waking up after that for some level of hierarchy of selves. The self born in the death of the self with an opposite arrow of time self has no direct memories about the state. Self can however have memories about dreams in which part of say brain is awake. These memories store information about what self experienced during the sleep.

   In BSFR the active boundary of the CD becomes passive and is frozen. The size of CD is scaled down so that CD becomes small: this implies that the reincarnated self has a childhood and much of the memories - often not pleasant - stored near the active boundary as subselves living forth and back as conscious entities disappear. The surviving memories of self become "silent wisdom" of the reincarnated self.

4. If CD belongs to a larger CD, call it CD_{super} representing a larger unit of consciousness, the sub-CDs must shift to the same direction as the active boundary of CD_{super}. Otherwise the sub-CDs would drop from the flow of consciousness. This is analogous to co-movement of matter in cosmology.

   Note that the mental images of self correspond to sub-CDs around T_{now} and shift towards geometric future as CD increases and new mental images emerges at T_{now} plane: by $M^8 - H$ correspondence these special moments in the life of self correspond to roots of the polynomial defining space-time surface and reside are the upper half-cone of the CD. As CD increases, new roots pop up inside the upper half-cone near the T_{now} hyper-plane for some particular SSFRs. Completely counterintuitively, the mental images about past experiences are therefore in the geometric future of T_{now} hyperplane!

The proposed picture must be consistent with everyday experience. Call the two periods of self sleep wake-up and sleep label the two different BSFRs by "sleep" and "wake-up".

1. In each SSFR CD size increases - at least in statistical sense this implies that T grows. Each SSFR corresponds to a scaling for the CD shifting its active boundary towards the geometric future. During its life cycle CD experiences scaling Λ:

$$T_{now} \to T_{now,sleep_1} = \Lambda(SSFR)T_{now} \ , \ \Lambda(SSFR) > 1 \ .$$

2. When the system falls in sleep the size of CD is scaled down so that also the value of T_{now} is scaled down by $\Lambda_{BSFR} < 1$:

$$T_{now,sleep_2} = (1-\Lambda(BSFR))2T_{now,sleep_1} = (1-\Lambda(BSFR))\Lambda(SSFR)2T_{now} \ , \ \Lambda(BSFR) < 1 \ .$$

After that the CD begins to increase in size by small scalings in SSFRs to opposite time direction and T_{now} begins to decrease from its value $T_{now,sleep}$ begins to decrease.

3. If CD belongs to a bigger CD - call it super-CD - representing a larger unit of consciousness with a longer life cycle, one can argue that the CD must shift to the same direction as the larger CD increases. Otherwise the CD would drop from the flow of consciousness defined by super-CD. This is analogous to co-movement of matter in cosmology. Therefore a given life cycle corresponds also a shift ΔT of sub-CDs towards the growth direction of super-CD takes place and one has for the time coordinate $T_{super,now}$ of the super-CD. Therefore one must perform shift$T \to T + \Delta T$ for $T_{now,sleep_1}$ and $T_{now,sleep_2}$ to take into account the drifting. This gives for the moments "Now" before ad after the shrinking of CD in BSFR (falling asleep):

$$T_{super,now,sleep_1} = T_0 + T_{now,sleep_1} + \Delta T \ ,$$

$$T_{super,now,sleep_2} = T_0 + (1 - \Lambda(BSFR))2T_{now,sleep_1} + \Delta T \ .$$

4. Similar formula holds true for the moment of wake-up. In the previous formula T_{now} is replaced with $T_{now,sleep_2}$ and one has

$$T_{super,now,wakeup_1} = T_0 + \Lambda^{1)}(SSFR)T_{now,sleep_2} + \Delta T^{1)} \ ,$$

$$T_{super,now,wakeup_2} = T_0 + (1 - \Lambda^{1)}(BSFR))\Lambda^{1)}(SSFR)2T_{now,sleep_2} + \Delta T^{1)} \ .$$

The parameter T_0 depends on the choice of the origin of time for super-CD but is irrelevant.

One can deduce a consistency condition for the parameters of the model.

1. During the sleep period the time coordinate $T_{super,now}$ for moment "Now" in the coordinates of larger CD changes in the following manner:

$$T_{super,now,sleep} = T_0 + T_{now,sleep_1} \to T_{super,now,wakeup}$$

$$= T_0 + \Lambda^{1)}(BSFR)T_{super,now,sleep_2} + \Delta T^{1)} \ .$$

T_0 is an irrelevant parameter associated with super-CD. Note that there is breaking of time reversal symmetry since self associated with CD_{super} has fixed arrow of time unlike CD. Hence ΔT has at least in a statistical sense the same sign irrespective of the arrow of time of self.

2. This picture should be consistent with what we observe. When the tired average self fall a sleep at the evening, it wakes wake-up at the morning and is full of energy. Quite generally, wake-up occurs after time $\Delta T(sleep)$ meaning that the value of time T_{super} has increased by

$$T_{super,now,wakeup} = T_{super,now}(sleep_1) + \Delta T(sleep) \ .$$

These two expressions for the value of $T_{super,now}(wakeup)$ must be consistent and this gives a conditions on the parameters involved:

$$(1-\Lambda^{1)}(BSFR))\Lambda^{1)}(SSFR)2T_{now,sleep_1}+\Delta T^{1)}$$

$$=T_{now,sleep_1}+\Delta T+\Delta T(sleep)\ .$$

$\Delta T(sleep)$ is given by

$$\Delta T(sleep)=[(1-\Lambda^{1)}(BSFR))\Lambda^{1)}(SSFR)2-1]T_{now,sleep_1}+\Delta T^{1)}-\Delta T\ .$$

Intuitively it seems clear that for a given arrow of time it is not possible to wake-up before one falls asleep, and the condition $\Delta T(sleep) > 0$ for the standard arrow of time gives a constraint on the parameters. One cannot however exclude the possibility of time travel without dying or falling asleep first of the duration of time travel is much longer than that of wave-up period: $\Delta T^{1)} - \Delta T$.

A special solution corresponds to $\Delta T(sleep) = \Delta T^{1)} - \Delta T$ and $(1-\Lambda^{1)}(BSFR))2\Lambda^{1)}(SSFR) = 1$ giving $T_{now,sleep_2} = T_{now}$.

4 Still about quantum measurement theory in ZEO

The relation between zero energy ontology (ZEO) based quantum measurement theory and adelic vision could be much clearer. The following considerations suggest a more precise picture about cognitive representations and formulation of quantum measurement theory for them.

In the sequel ZEO based theory of consciousness [L18, L35] as quantum measurement theory is discussed first by starting with a criticism of physicalism and after that introducing ZEO based view about consciousness as quantum measurement theory as a solution to the problems of physicalism.

After this the relation between zero energy ontology (ZEO) based quantum measurement theory and adelic vision [L17, L16] is discussed. The considerations suggest a more precise picture about cognitive representations and formulation of quantum measurement theory for them. One can generalize classical cognitive representations as number theoretical discretizations of space-time surfaces in the extension of rationals considered to their quantum counterparts as wave functions in the Galois group of the extension and introduce also fermions as spinors in the group algebra of Galois group. The strongest option is purely number theoretical representations of spinors as spinors in this group algebra. Presumably however M^8 spinors are required and have interpretation in terms of octonion structure.

An attractive vision is that number theoretical quantum measurements reduce to measurement cascades involving a sequence of state function reductions reducing the entanglement between wave functions in sub-Galois group H and group G/H and ends up to a prime Galois group for group algebra has prime dimension and represents Hilbert space prime not decomposable to tensor product.

Also time measurement is considered from the number theoretic perspective assuming $M^8 - H$ duality [L28]. Clock readings are realized as roots of the rational polynomial determining the space-time surface in M^8. Time measurement would involve a localization to a definite extension of rationals, whose dimension n must be proportional to the temporal distance T between the tips of causal diamond (CD) to guarantee fixed time and energy resolution.

4.1 ZEO based theory of consciousness as quantum measurement theory

Consider first zero energy ontology (ZEO) based quantum measurement theory as a theory of consciousness.

4.1.1 Criticism of physicalism

It is good to start with a criticism of physicalism.

1. In physicalism consciousness would reduce to a physical property, like energy, momentum or charge and one would have the hard problem. There would be absolutely no idea why for instance sensory qualia emerge and how they correspond to sensory input. For instance, the

assignment of sensory qualia to brain regions leads to a mystery: auditory, visual, etc. areas look exactly the same. How they can give rise to so different qualia?

Remark: The answer to the question is that this is not possible. I n TGD framework macroscopic quantum coherence and ZEO allow to assume that sensory qualia are seated at sensory organs [L10].

2. This is not the only problem: free will is not possible and we must stop talking about ethics and moral as we have indeed done in modern free market economy, which threatens to destroy our civilization.

3. The third problem of physicalism and also idealism is that conscious experience is about something: it carries information about something, external world, my body, even about my thoughts. It is associated with a pair of systems- me and the rest of the world - rather than single system as consciousness as a physical property implies. This "aboutness", kills the physicalistis view and actually idealism and under reasonable assumptions also dualism. Standard ontologies of consciousness fail.

Physicalistic approach has also problems with quantum measurement theory. The basic problems are basically due to the fact that observer as a conscious entity remains an outsider: observations affect the measured system but theory cannot say anything about observer as subjective entity. In ZEO the situation is different [L35] (`http://tinyurl.com/wd7sszo`) .

1. Quantum jump defines the basic building brick of conscious experience. It is something between two different quantum worlds, not in the world as a physical property of quantum system. Consciousness is a moment of re-creation. This a solves the hard problem and problem of free will.

2. Also the paradox of state function reduction can be solved if one can understand the problems related to the notion of time. There are two times: experienced time and geometric time, or the clock time. They are very different. Experienced time irreversible and has preferred moment "Now". Geometric time reversible and without preferred "Now". For some reason these times have been however identified.

4.1.2 ZEO based quantum measurement theory

In ZEO physical states as time= constant snapshots are replaced by pairs of "initial" and "final" states A and B or - by holography - with superpositions of deterministic time evolutions from A to B with respect to geometric time - note the analogy with computer program in computer science, behavior pattern in neuroscience, and function in biology.

1. In "small" state function reductions (SFRs) -"weak" measurements - the superposition of time evolutions from A to B is replaced with a new one such that states A at passive end - "initial state" - are not changed. Classical determinism is respected although one has quantum jump and generalization of quantum measurement theory. Two times - two causalities. The temporal distance T between A and B increases in statistical sense and this gives the correspondence between experienced time as sequence of state function reductions and geometric time is identified as T. These measurements changing B correspond to "weak" measurements analogous to classical measurements and to sensory input. A represents permanent part of selfness, "soul" one might say.

2. In "big" (ordinary) state function reductions (BSFRs) the roles of "initial" and "final" states change and the arrow of geometric time changes. Self dies and reincarnates with an opposite arrow of geometric time.

3. In more precise view the pairs of time=constant snapshots are replaced with what I call causal diamonds (CDs). The assumption that the size of CD is preserved In BSFR as assumed originally leads to some paradoxical looking implications. For instance, the size of CDs assignable to our sub-selves identifiable as mental images would increase without bound. $M^8 - H$ duality suggests strongly that the sizes of CDs can decrease in BSFR:

the formerly active boundary would be frozen but the temporal distance of formerly passive boundary would be reduced so that the size of CD would decrease. One could say that self has childhood and starts from scratch with all sins of previous life forgiven.

This picture about state function reduction finds considerable empirical support.

1. The paradoxical experimental findings of Minev *et al* in atomic systems challenging standard quantum measurement theory give strong support for the reversal of the arrow of time in BSFR [L25] [L25] (`http://tinyurl.com/yj9prkho`).

2. Also Libet's finding that experience of free will [J1] seems to be preceded - caused - by neural activity, can be understood. It is not anymore support for the claim that free will is an illusion. State function reduction changing time order happens, and free will causes neural activity in the geometric past.

3. There is are lot of support for the new view about time from biology. For instance, self-organization - not only biological - could be understood as involving time reversal meaning that the time reversed reduction of order implied by generalization of second law looks from standard observer's viewpoint like increase of order. Self-assembly and generation of structures in long scales would involve increase of time order. Evolution is second aspect of self-organization and reduces to the unavoidable increase of h_{eff} as dimension for extension of rationals. Also the need for energy feed - metabolic energy feed in living matter - can be understood because the increase of h_{eff} keeping other parameters constant, increases energy scale. Dark matter would be visible everywhere in sharp contrast with standard prejudices.

4. There is support even from cosmology and astrophysics, where TGD predicts quantum jumps in macroscopic scales. For instance, stars older than Universe can be understood in more detailed picture about ZEO [L26, L27] (`http://tinyurl.com/tf38xnx`).

One can of course criticize the view about the role of clock time as the distance T between the tips of CD as over-simplified [L35].

1. The state function reductions preceding SSFRs are preceded by unitary processes U. What one can say about "time evolution" U. First of all, U is assumed to produce a zero energy state de-localized in the space of CDs - in particular with respect to the distance T between the tips of CD.

   The simplest guess is that in SSFR a complete localization in T - measurement of T - and other moduli of CD (say boost with respect to the lower tip of CD) occurs. Can one reduce the localization in T to a SSFR reducing quantum entanglement or is time measurement something different? What entanglement of CD sizes with different values of T with the measurement apparatus could mean? What the presence of a measurement apparatus for time T - the clock at fundamental level, could mean mathematically? Later also the question whether one could reduce this measurement to pure number theory emerges?

2. The notion of completely localized state is over-idealization and also mathematically poorly defined. Gaussian wave packet over classical states with well-defined classical conserved energy (by Poincare invariance) with respect to T localized around some value T_0 is a more realistic notion and time measurement would mean localization to a wave packet around T_0.

   In [L35] the proposal that the time evolution of self could be seen an analog of cooling process analogous to cosmic cooling is considered. This would correspond to an adiabatic time evolution happening for a particle in box whose size increases slowly. In this process the coefficients in a superposition of states with given classical energy remain unaffected but the classical energies of the states themselves decrease. This would conform with Uncertainty Principle stating that the classical energies scale as $1/T$.

4.1.3 A more detailed view about quantum measurement in ZEO

Consider next in more detail what state function as quantum measurement means in TGD.

1. In standard quantum measurement theory quantum measurements are often thought to be performed by humans only. In TGD one assumes that state function reduction as analog of quantum measurement is universal and can take place for any pair of mutually entangled systems unentangled from its complement.

2. Density matrix for the entangled pair of systems is the fundamental observable. This applies to both BSFRs and SSFRs at active boundary of CD, which correspond to "weak" measurements commuting with the observables diagonalized at the passive boundary of CD and thus leaving the states at it invariant.

3. Quantum measurement involves typically measurement of several observables. This is realized as a measurement cascade. First the quantum measurement of density matrix occurs for some pair formed sub-system S_1 and its complement S_2 forming together system S. After the same occurs for S_1 and S_2. Observables correspond to density matrices in this cascade. One proceeds as along as new decompositions are found. If the final state belongs to a sub-space with prime dimension the cascade stops since there is no further decomposition to tensor product.

4. The density matrix for subsystem in general case decomposes to a sum of projectors t subspaces and the state function reduction takes to one of them. The outcome of the measurement can be sub-space rather than ray.

   Number theoretic vision suggests also a second possibility. The SSFR would take place only if the eigenvalue of density matrix having probability interpretation associated with the subspace or ray is in the extension of rationals associated with the matrix elements of the density matrix and space-time surfaces considered (defining the cognitive representation). If one assumes frequency interpretation of probability theory, this probability must be rationals. Entanglement can be number theoretically stable. This would that one can have stable entanglement.

   It is natural to assume that BSFR can can increase the extension of rationals associated with the eigenvalues of density matrix in the extension of the extension associated with its matrix elements.

5. Stable entanglement could be crucial for quantum computation as also the possibility of large values of h_{eff} and of time reversal. One can also assign to entanglement with coefficients in an extension of rationals p-adic variant of entanglement entropy by replacing logarithms of probabilities with the logarithms of their p-adic norms. These p-adic entanglement negentropies can be positive so that the entanglement carries information. This negentropy is different from the real negative entropy due to the loss of precise knowledge about entangled states. Quite generally, the sum of p-adic negentropies can be larger than real entropy. This would explain the paradoxical looking fact that highly evolved biological systems are highly entropic [I1] [L4]. england

4.2 The relationship between adelic physics and ZEO based quantum theory

The challenge is to formulate quantum measurement theory taking into account the constraints from adelic physics [L17, L16]. One can consider the possibility is that the quantum physics could reduces at the level of cognitive representations to purely number theoretic physics. This would mean huge simplification. I have considered quantum theory at the level of cognitive representations from the point of view of number theory in [L33] and from the perspective of scattering amplitudes in [L32].

4.2.1 Two kinds of cognitive representations

One can consider two kinds of cognitive representations. The cognitive representations considered hitherto correspond to number theoretical discretization of space-time surface determined by an extension of rationals, they are "classical". The bosonic wave functions in Galois group of extension acting on cognitive representations and their fermionic counterparts based on fermionic dynamics

in the group algebra of Galois group and its normal subgroups (Galois groups too) would define quantal cognitive representations.

1. There are cognitive representations both at the classical level in terms number theoretical discretizations of space-time surfaces defined by the extension of rationals and at the quantum level based on spinorial wave functions in Galois group of the representation. Also the spinorial wave functions in factor sub-groups and normal subgroups of Galois group are involved.

2. One can assign preferred primes p_{pref} to the classical space-time dynamics as ramified primes p_{ram} of the extension. For these the polynomial defining extension has double root in $O(p) = 0$ approximation. This would be the realization of quantum criticality for cognition: criticality is typically in potential models a situation in which two or more extrema of the potential function co-incide - catastrophe theory of Thom is classical example.

3. At the level of state (spinorial) space wave functions in Galois group acting on cognitive representations are natural candidate for a bosonic state space. Quantum states would be wave functions in Galois group G with normal subgroup H acting as a Galois group of lower-D extension.

   G/H is group itself and one can express wave functions in G as superpositions of products wave functions in G/H and H. The wave functions in G/H and H define naturally a tensor product and an attractive idea is that state function reduction can be regarded as measurement in G/H or equivalently in H. When H has prime order further reduction is not possible since Hilbert spaces with prime dimension are primes of tensor product.

   A natural candidate for preferred primes p_{pref} is as orders of smallest possible normal sub-groups of Galois group, kind of primitive generating Galois groups.

   Remark: One must consider also the possibility that quark and possibly also leptonic degrees of freedom are present as additional spinor indices. The fact that M^8 has octonionic structure could require also M^8 spinor structure.

4. In TGD dark matter is identified as $h_{eff} = n \times h_0$ phases of ordinary manner. n is identified as the order of Galois group of Galois extensions and thus of the extension itself. For ordinary value of Planck constant empirical inputs suggests the identification $h = 6h_0$ [L7, L20].

   Quite interestingly, one has $6 = 2 \times 3$ so that there is factorization to 2-D and 3-D subspaces assignable to massless particles, and massive gauge bosons. This indeed suggests that number theoretical vision could allows to represent all many-particle states in terms of wave functions (spinor fields) in the group algebra of Galois group.

5. How to construct cognitive representations for fermions? A natural generalization of the bosonic dynamics in n-D group algebra of Galois group is introduction of spinor structure in terms of 2^k-dimensional spinors in the group algebra. For $k = n$ both chiralities are present and for $k = n-1$ only second chirality. In fact, one could pose even more chirality conditions giving $2^{n/2}$-D ($[n+1]/2$-D) spinors for even (odd) n. Indeed, the recent view about SUSY in TGD framework suggests that only quarks - second embedding space chirality - appear as fundamental fermions and that leptons are local composites of 3 quarks - spartners of quarks in well-defined sense [L36] (`http://tinyurl.com/y4pdb2xz`).

   The simplest option is that at the level of cognitive representations the fermionic oscillator operator algebra corresponds to the oscillator operator algebra creating fermions states having at most $k = n$, $k = n-1$,...$n/2$ ($[n+1]/2$) fermions assignable to these spinors in finite measurement resolution. Entire quantum dynamics at the level of cognitive representations would reduce to the dynamics of fermions in the group algebra of Galois group and its Galois sub-groups.

6. There is also question about the Galois groups of the extensions of various p-adic number fields Q_p induced by the extension of rationals with dimension n. For p-adic numbers in approximation the extension reduces to a finite field $G(p,k)$, $k \leq n$, and one has k-dimensional extension. Galois group G_p is smaller than the Galois group G for rationals. G_p would act

naturally in the p-adic counterparts of cognitive representations and the representations of G would reduce to direct sums of representations of G_p. Note that the distinction between sensory and cognitive (real and p-adic) would emerge only at the quantum level.

For $p < n+1$ the fact that one has $x^{p-1} = 1$ for $G(p)$ implies that the irreducible polynomial P defining the extension Q reduces to a polynomial with degree $nmodp-1 \leq p-1$. Information is lost for $p < n+1$. For $p \geq n+1$ situation is different but also in this case the reduction occurs for ramified primes since polynomial P as in this case multiple roots. This would be the counterpart of quantum criticality at the level of cognitive representations.

7. Could the primes appearing as factors of n be preferred p-adic primes? Since these primes as p-adic primes mean a loss of information, they are distinguished but hardly preferred in p-adic evolution. Ramified primes larger than n are more plausible candidates and can be assigned even with polynomials of order 2. The preferred p-adic primes assignable to elementary particles are indeed large: electron would correspond to $M_{127} = 2^{127} - 1 \sim 10^{38}$ [K15].

4.2.2 Quantum measurement theory for cognitive representations

What can one say about quantum measurement theory for cognitive representations? The basic questions concern the tensor products. How many tensor factorizations there are and can one pose some conditions on them? Assume that fermionic Fock states for second quantized spinor fields in n-D group algebra are enough for quantum physics at the level of cognitive representations.

1. Tensor product decomposition for n-D group algebra corresponds to the factorization $n = k \times l$. All factorizations of n define a possible quantum measurement situation and state function reduction can take place in bosonic sector to k or equivalently l-dimensional space. These factorizations would be highly unique since they correspond to pairs of Galois group G and its Galois subgroup H. They are defined modulo discrete automorphism of G. It is not clear whether the choice of this automorphism has physical content: one might consider a discrete variant of gauge invariance.

   For the fermionic oscillator algebra analogous statement holds true. Now the decompositions are induced by $n = k \times l$ decompositions.

2. State function reduction cascades would correspond to sequences of Galois subgroups $G \supset G_1 \supset ....G_k$ such that G_k corresponds to either trivial group of group with prime order. In this case the final state would be reached by a factorization in which the density matrix for G_k does not allow eigenvalues in the extension considered. This extension could be G, G_1 or perhaps rationals (frequency interpretation for probabilities).

4.2.3 $M^8 - H$ duality and measurement cascade

$M^8 - H$ duality [L28] suggests much more concrete picture about the measurement cascade.

1. $M^8 - H$ duality predicts that the roots r_n of a rational polynomial defining the space-time surfaces at the level of M^8 correspond "very special moments in the life of self" $t = r_n$ for the M^4 linear time in the rest system of CD, and that once these moments have been experienced, BSFR can take place. This is possible but not the only possible interpretation.

2. $M^8 - H$ duality and the view about evolution as analog of genetic evolution in which genes are conserved suggests that the polynomials can be regarded as functional composites of simple polynomials $P = P_{n_1} \circ P_{n_2} \circ ...P_{n_k}$ satisfying $P_{n_r} = 0$ (n_i refers to the degree of the polynomial). P possesses the roots of P_i and the corresponding Galois groups as normal subgroups as the counterpart for the conservation of genes in evolution.

   One can distinguish also primitive polynomials as those defining extensions which do not decompose further. Galois groups with prime number of elements corresponds to such extensions. Note that the same extension can appear at several levels in hierarchy and would correspond to a realization of extension at different hierarchy level defining a kind of abstraction level.

3. Intuitively the measurement cascade should correspond to a cascade proceeding to shorter time and length scales by increasing the resolution and also to a process in which abstraction is gradually concretized.

   Could the measurement cascade for a state localized to a given extension of rationals start with the measurement of the root set $X_1 = \{r_{1,1}\}$ of P_{n_1} corresponding to the lowest time resolution. After than P_2 and the root set $X_2 = \{r_{2,i}\}$ would be measured meaning a refined of time resolution replacing $r_{1,i}$ with as subset of X_2 around it.

   Here one must be however very cautious: one could also consider a hierarchy of CDs with decreasing size scales as the counterpart of the measurement cascade. I do not understand well enough the scale hierarchy to answer the question whether these two views might relate.

4.2.4 Measurement of time number theoretically

Could the measurement of clock time T as (average) distance between the tips of CD [L35] be understood as number theoretical measurement?

1. What about the measurement of time as the distance T between tips of CD or more generally as the center of mass value T_0 of T in the case that one has Gaussian wave packets localized around varying T_0? How could one realize the measurement apparatus - the clock - in terms of entanglement?

   Suppose that the superposition over CDs with different values of T corresponds at the level of space-time surfaces in M^8 to that for space-time surfaces determined by polynomials P_n with varying degrees and rational coefficients. The measurement fixing the extension and Galois group would not fix P_n since there is a large number of polynomials with rational coefficients but same Galois group. The measurement fixing the extension leads to a partial (at least) localization in T or T_0 but this is not expected to be enough.

2. A stronger localization in the state function reduction measuring n would require that T or T_0 correlates with the degree n. How could this be achieved in a natural manner? Intuitively the requirement of some fixed time resolution based on the preferred moments $t = r_n$ interpreted as clock readings has fixed resolution as the average time lapse $\Delta T = \langle \Delta T_{i,i+1} = r_{i+1} - r_i \rangle$ would require $n \propto T$ or $n \propto T_0$. How could this be achieved concretely? Could one specify the zero energy states by giving the time resolution as ΔT and being equivalent to energy resolution. This would also dictate the resolution of the cognitive representation as the set of space-time points in the extension.

5 Some questions concerning zero energy ontology

Zero energy ontology (ZEO) [L35] gives rise to quantum measurement theory, which naturally extends to a theory of consciousness. In this article also consciousness aspect is central and my sincere hope is that it would not expel those physicist readers for whom consciousness still remains an unscientific notion.

5.0.1 Zero energy ontology (ZEO) briefly

ZEO provides a new ontology solving the key problem of the standard quantum measurement theory and quantum theory itself. It must be emphasized that ZEO is not a new interpretation created to put under the rug the logical paradox due to the conflict between non-determinism of state function reduction (SFR) and the determinism of unitary time evolution. Also the problem about the scale in which quantum world becomes classical disappers: the Universe is quantal im all scales and ZEO view about quantum jump makes the Universe to look like classical.

1. At the level of space-time dynamics, the notion of preferred extremal (PE) as a space-time surface is central: PE is an extremal of an action principle, which by general coordinate invariance must be highly unique once its intersection with either boundary of causal CD $= cd \times CP_2$ (cd is the intersection of future and past directed light-cones of M^4) is given.

In the ideal situation this implies holography. Space-time surface is an analog of Bohr orbit and classical theory is an exact part of quantum theory.

There is probably a finite and discrete non-determinism analogous to that associated with soap films spanned by a frame: space-time is indeed a minimal surface as also soap films, and the 3-surfaces at its ends at boundaries of CD are part of the frame. Besides space-time surface is an extermal for Kähler action analogous to Maxwell action. The challenge is to interpret this finite non-determinism.

2. Quantum states, which I call zero energy states, can be interpreted as pairs of analogs of ordinary 3-D quantum states with positive energy. The members of the pair are at the opposite boundaries of CD. The convenient convention used also in quantum field theories (QFTs) is that the conserved quantum numbers at opposite boundaries sum up to zero classically: this brings in nothing new. At quantum level, 4-momenta are conserved only at the limit when CD has infinite size whereas classically the conservation holds true for all CD sizes: this reflects the Uncertainty Principle [L53]. Also in QFTs exact momentum conservation is obtained only at the limit of infinite quantization volume.

   At the space-time level, zero energy states can be regarded also as superpositions of deterministic time evolutions: this is central for the interpretation.

3. SFRs are quantum jumps between zero energy states. SFR does not affect any deterministic time evolution but only replaces their superposition with a new one. This solves the paradox that was one of the key motivations for ZEO.

4. Zeno effect strongly suggests that there are 2 kinds of quantum measurements assignable to SFRs. For "weak measurements", "small" SFRs (SSFRs), the component of zero energy state at the either boundary of CD, to be called passive boundary (PB), is unaffected. Also the PB is unaffected apart from scaling. At the active boundary (AP) state changes and AP is scaled up (at least in statistical sense) and due to the scaling shifts to the geometric future.

   The unitary time evolution preceding each SSFR corresponds to a scaling of CD (or rather, its M^4 projection cd) rather than time translation as its counterpart in string models. In A unitary evolution B between two SSFRs a superposition of CDs with varying sizes is formed and SFR localizes CD to a fixed size, which means the measurement of geometric time identifiable as the distance between the tips of CD. This geometric time correlates with the subjective time defined by the sequences of SSFRs. Subjective and geometric times are not identical as in standard ontology but only correlated.

5. "Big" SFRs (BSFRs) are the counterparts of ordinary quantum measurements. In the BSFR the roles of AB and PB of CD change so that the arrow of time changes since CD increases in the opposite direction of time (at least in statistical sense). For an observer with an opposite arrow of time, BSFR looks like an average deterministic time evolution leading to the final state of BSFR as observed experimentally by Minev *et al* [L25] [L25]. This illusion makes BSFR look classical in all scales although the TGD based dynamics is quantal in all scales due to the hierarchy of Planck constants predicted by TGD.

   The possibility of time reversal forces a generalization of thermodynamics to allow both arrows of time: this kind of generalization was proposed long ago by Fantappie [J2] with motivation coming from biology. Quite generally, self-organization processes seem to violate the arrow of time. External energy feed explains this partially but BSFR would be an important additional element of self-organization [L31, L51], especially so in living matter.

   The assignment of "free will" to BSFR allows us to understand how free will can be consistent with the classical non-determinism of physics which would be exact.

ZEO based quantum measurement theory and therefore also physics naturally extends to a theory of consciousness, and one cannot avoid using this word, which is still a cursed word in the physicalistic camp.

5.0.2 Problems related to the mathematical realization of ZEO

There are several open questions related to ZEO and TGD inspired theory of consciousness and the existing view involves several working hypothesis which should be reduced to deeper principles or shown to be wrong.

At least the following questions related to physical interpretation of ZEO are still waiting for a detailed answer.

1. Preferred extremal (PE) property of space-time surfaces is central for quantum TGD [L44]. It follows from holography forced by general coordinate invariance (GCI), which however need not be ideal. How uniquely does the PE property of the space-time surface fix the space-time surface inside a given CD? The simplest situation is that the data at the end of the space-time surface at either boundary of the CD,fixes it completely. Space-time surface would be an analog of Bohr orbit.

   Full determinism would imply that WCW for CD effectively reduces to the space of 3-surfaces assignable to either end of CD. The dynamics of SSFRs would reduces to that in fermionic degrees of freedom assignable to Boolean cognition since WCW degrees of freedom assignable to sensory perception would be fixed.

   However, the dynamics of soap films spanned by frames suggests that this is not the case. The 3-D ends of the space-time surface define a frame and also dynamically generated portions of frame are allowed by the variational principle defined by the sum of a volume term and Kähler action as an analog of Maxwell action. The coefficient of the volume term has an interpretation in terms of a length scale dependent cosmological constant Λ.

   Outside the frame space-time surface would be at least for a very large portion of extremals an analog of complex surface and therefore a minimal surface [L54] and also an extremal of Kähler action. At the frames only the equations for the entire action (sum of volume term and Kähler action) would be satisfied. The divergences of the conserved isometry currents for the volume term and Kähler action would have delta function type singularities but they would cancel each other. The portions of the frame could be analogous to singularities of analytic functions such as cuts and poles.

2. Number theoretic universality [L16, L17] in turn suggests that the inherent non-determinism of p-adic differential equations [K19] [L35] proposed to be a correlate of imagination could also relate to this non-determinism. How do the non-determinism of space-time surface, p-adic non-determinism, and non-determinism of the state function reduction relate to each other: could they be even one and the same thing?

ZEO based quantum measurement theory defines a theory of consciousness. How unique is the interpretation of zero energy ontology (ZEO) [L35]? Here 3 options suggest themselves corresponding to "western" and "eastern" world views and their hybrid.

1. For the western option, the space-time surface continues outside any CD as external world, in particular sub-CD and sub-CD is a correlate for the perceptive field of self.

2. For the eastern option, space-time ends at the boundary of any CD and sub-CD is not a correlate for the perceptive field of self and there is no constraint from the external world at boundaries of CD.

3. For the hybrid of these two options, conscious entity corresponds to a hierarchy of CD for which the highest level corresponds to CD for which space-time does not continue outside the CD. The highest level represents a God-like entity.

5.0.3 Problems related to ZEO based theory of consciousness

The new picture about sub-CDs at WCW level raises questions related to the TGD inspired theory of consciousness. This view involves several ad hoc assumptions related to the notions such as attention, mental image, memory, volition and intentions. Do these assumptions follow from more general assumptions or can some of them be simply wrong?

1. CD is a correlate for the perceptive field of self. Sub-CDs of CD define perceptive fields of subselves identified as mental images. What is the precise definition of sub-CD? Can one say that a sub-CD is created when a mental image is created. How does this happen? What determines the position and size of the sub-CD?

   The sub-CD is defined by the restriction of zero energy state to sub-CDs so that sub-CDs are induced by CD. This condition is analogous to boundary condition in classical physics and freezes WCW degrees of freedom of sub-CD at the passive boundary (PB) but the failure of determinism leaves discrete degrees of freedom at the active boundary (AB) so that the dynamics of SSFRs is restricted to these sub-WCW degrees of freedom and fermionic degrees of freedom.

2. Where sub-CDs and subselves are located? The natural location for a minimal sub-CD and mental images is around 3-surface at which the classical non-determinism fails: the frames of the soap film in soap film analogy. One can develop a rather detailed picture about frames [L54] based on number theoretic vision realized in terms of $M^8 - H$ duality [L41, L42, L46].

3. How sub-selves (sub-CDs) are created? Can they disappear? The notion of attention as generation of sub-CD achieved by a location of WCW ("world of classical worlds") spinor field at spacetime surfaces having their intersection with the PB of CD in a fixed set of 3-surfaces defining the sub-WCW is highly suggestive. This also affects the WCW spinor field of CD.

   The attention can be directed in several ways. Redirection of attention means a movement of the region defining the content of mental images in the interior of a CD. Entanglement and classical communications would be naturally associated with attention defined in this manner. If minimal subselves are associated with the frames as loci of classical non-determinism, the set of targets of attention is discrete and finite.

   This view about attention makes it possible to see also memory, anticipation, and intentions as special cases of attention.

4. The time evolution of CD itself would correspond to a scaling of CD (rather than translation), which by the failure of strict determinism brings in new discrete degrees of freedom related to the new frames becoming into the daylight as space-time surfaces increase. In the new picture, the sub-WCW property poses strong restrictions to the earlier picture about the development of sub-CD. The idea about silent wisdom as mental images preserved from the previous life after BSFR is not lost but is considerably modified.

   In this picture, the small failure of classical determinism would be an absolutely essential element in that it makes possible a non-trivial theory of consciousness at the level of CD and at space-time level. Otherwise would have only fermionic degrees of freedom forgiven sub-CD. What is intriguing is that everything would be finite. SFRs would involve choices between finitely many alternatives and in this respect the theory would be analogous to the computationalistic approach: in fact, preferred extremals are analogous to computer programs.

5.1 Some background

In the sequel, some understanding of the basic ideas and notions of TGD proper [L44] is needed. Also ZEO as the target of critical discussion is briefly summarized.

5.1.1 TGD view briefly

Very concisely, TGD emerges as fusion of special and general relativities and has Poincare invariance of special relativity and General Coordinate Invariance (GCI) and Equivalence Principle (EP) as basic principles. Also the interpretation as a generalization of string models is possible: point-like particles are replaced by 3-surfaces instead of strings and world lines become space-time surfaces.

The notion of induction makes it possible to eliminate classical boson fields as primary dynamical variables and reduce them to the sub-manifold geometry of the space-time surface. For the

simplest option, free second quantized quark fields of the embedding space $H = M^4 \times CP_2$ induced to the space-time surface remain as fundamental fermion fields and quarks serve as basic building bricks of both bosons and fermions as elementary particles [L36, L47].

Some understanding of notions such as the "world of classical worlds" (WCW) [K21], preferred extremal (PE) [K3], and various variants of holography [L41, L42] implied by general coordinate invariance (GCI) in TGD framework is assumed. Inclusions of hyperfinite factors of type II_1 (HFFs) [K25, K13] are central elements of quantum TGD proper.

Adelic physics [L17, L16] replacing real number based with number theoretical universal physics based on the hierarchy of adeles defined by extensions of rationals (EQs) and $M^8 - H$ duality (see Appendix 5.6) allowing number theoretic and geometric views about physics dual to each other is also assumed as the background.

Hierarchy of Planck constants $h_{eff} = n \times h_0$, with n identified as dimension of EQ, is the basic implication of adelic physics and central for quantum TGD. The phases labelled by h_{eff} behave like dark matter [K6, K7, K8, K9]. This hierarchy serves as a correlate for quantum criticality in arbitrarily long length scales.

Cognitive representations identified as points of space-time surface for which preferred coordinates of embedding space are in an extension of rationals are also central for the construction of the theory using $M^8 - H$ duality [L41, L42].Galois group of EQ becomes number theoretical symmetry and is central in the description of quantum variants of cognitive representations [L2, L45].

Zero energy ontology (ZEO) [L35] is a key notion of quantum measurement theory. The basic prediction is that time reversal occurs in the ordinary state function reduction (SFR). This has profound implications for the interpretation of the quantum measurement theory [L25].

TGD inspired theory of consciousness can be seen as an extension of quantum measurement theory and relies on Negentropy Maximization Principle (NMP) as a basic dynamical principle [K17] [L51] implying second law for ordinary entanglement entropy.

5.1.2 $M^8 - H$ duality as it is towards the end of 2021

The view of $M^8 - H$ duality (see Appendix 5.6) has changed considerably towards the end 2021 [L53] after the realization that this duality is the TGD counterpart of momentum position duality of wave mechanics, which is lost in QFTs. Therefore M^8 and also space-time surface is analogous to momentum space. This forced us to give up the original simple identification of the points $M^4 \subset M^4 \times E^4 = M^8$ and of $M^4 \times CP_2$ so that it respects Uncertainty Principle (UP).

The first improved guess for the duality map was the replacement with the inversion $p^k \to m^k = \hbar_{eff} p^k/p^2$ conforming in spirit with UP but turned out to be too naive.

The improved form [L53] of the $M^8 - H$ duality map takes mass shells $p^2 = m^2$ of $M^4 \subset M^8$ to cds with size $L(m) = \hbar_{eff}/m$ with a common center. The slicing by mass shells is mapped to a Russian doll like slicing by cds. Therefore would be no CDs in M^8 contrary to what I believed first.

Quantum classical correspondence (QCC) inspires the proposal that the point $p^k \in M^8$ is mapped to a geodesic line corresponding to momentum p^k starting from the common center of cds. Its intersection with the opposite boundary of cd with size $L(m)$ defines the image point. This is not yet quite enough to satisfy UP but the additional details [L53] are not needed in the sequel.

The 6-D brane-like special solutions in M^8 are of special interest in the TGD inspired theory of consciousness. They have an M^4 projection which is $E = E_n$ 3-ball. Here E_n is a root of the real polynomial P defining $X^4 \subset M^8_c$ (M^8 is complexified to M^8_c) as a "root" of its octonionic continuation [L41, L42]. E_n has an interpretation as energy, which can be complex. The original interpretation was as moment of time. For this interpretation, $M^8 - H$ duality would be a linear identification and these hyper planes would be mapped to hyperplanes in $M^4 \subset H$. This motivated the term "very special moment in the life of self" for the image of the $E = E_n$ section of $X^4 \subset M^8$ [L28]. This notion does not make sense at the level M^8 anymore.

The modified $M^8 - H$ duality forces us to modify the original interpretation [L53]. The point $(E_n, p = 0)$ is mapped $(t_n = \hbar_{eff}/E_n, 0)$. The momenta (E_n, p) in $E = E_n$ plane are mapped to the boundary of cd and correspond to a continuous time interval at the boundary of CD: "very special moment" becomes a "very special time interval".

The quantum state however corresponds to a set of points corresponding to quark momenta, which belong to a cognitive representation and are therefore algebraic integers in the extension

determined by the polynomial. These active points in E_n are mapped to a discrete set at the boundary of cd(m). A "very special moment" is replaced with a sequence of "very special moments".

So called Galois confinement [L46] forces the total momenta for bound states of quarks and antiquarks to be rational integers invariant under Galois group of extension of rationals determined by the polynomial P [L53]. These states correspond to states at boundaries of sub-CDs so that one obtains a hierarchy. Galois confinement provides a universal number theoretic mechanism for the formation of bound states.

5.1.3 ZEO

The TGD based view of consciousness relies on ZEO solving the basic paradox of quantum measurement theory. First, a brief summary of the recent view of ZEO [L35] is required. Some aspects of this view will be challenged in the sequel for sub-CDs.

1. The notion of a causal diamond (CD) (see **Fig. ??**) is a central concept. Its little cousin "cd" can be identified as a union of two half-cones of M^4 glued together along their bottoms (3-D balls). The half-cones are mirror images of each other. CD=$cd \times CP_2$ is the Cartesian product of cd with CP_2 and obtained by replacing the points of cd with CP_2. The notion of CD emerges naturally in the number theoretic vision of TGD (adelic physics [L16])via the $M^8 - H$ duality [L30, L41, L42].

2. In the ZEO, quantum states are not 3-dimensional if the classical determinism does not fail as it actually does, but superpositions of 4-dimensional deterministic time evolutions connecting ordinary 3-dimensional states. By holography forced by general coordinate invariance, time evolutions are equivalent to pairs of ordinary 3-D states identified as initial and final states of time evolution.

   Quantum jumps replace this state with a new one: a superposition of deterministic time evolutions is replaced by a new superposition. The classical determinism of individual time evolution is not violated. This solves the basic paradox of quantum measurement theory. There are two kinds of SFRs: BSFRs (counterparts of ordinary SFRs) changing the arrow of time (AT) and SSFRs (analogs of "weak" measurements) preserving the arrow of time that give rise to an analog of the Zeno effect (`https://cutt.ly/yl7oIUy`) [L35]. The findings of Minev *et al* [L25] provide strong support for ZEO [L25].

To avoid confusion, one may emphasize some aspects of ZEO.

1. ZEO does not mean that the physical states identified in standard quantum theory as 3-D time= constant snapshots - and assigned in ZEO to the opposite boundaries of a causal diamond (CD) - would have zero energy. Rather, these 3-D states have the same conserved quantities, such as energy. Conservation laws allow us to adopt the convention that the values of conserved quantities are opposite for these states so that their sum vanishes.

   This is not new: in quantum field theories (QFTs), one speaks, instead of incoming and outgoing particles, external particles arriving from the geometric past and future and having opposite signs of energy. That conserved quantities vanish in the *4-D* sense, expresses only the content of conservation laws. A weaker form of this condition [L50] states that the total conserved Poincare charges are opposite only at the limit of infinitely large CD. CD would be an analog of quantization volume in QFTs, whose finiteness implies a small conservation of momentum.

2. ZEO implies *two* times: subjective time as a sequence of quantum jumps and geometric time as a space-time coordinate: for instance, the proper time of the observer. Since subjective time does not correspond to a real continuum, these times are not identifiable but are strongly correlated. This correlation has led to their identification although they are different.

5.2 How uniquely PE property fixes the space-time surface?

How uniquely the PE property fixes the space-time surface if its 3-D intersections with the boundaries of CD are given? This is the key question in this section.

5.2.1 Various variants of holography

General coordinate invariance (GCI) forces holography in the TGD framework. One can however consider several variants of holography [L41, L42, L51].

1. Holography in the standard sense would fix the space-time surface from the data of its intersection with either boundary of CD or the data associated with the light-like 3-surfaces at which the signature of the induced metric changes.

2. Strong form of holography (SH) states that 2-D data at the intersections of the light-like 3-surfaces and boundary of CD are enough to determine the space-time surface.

3. The strongest form of holography inspired by $M^8 - H$ duality [L41, L42, L50] states that space-time region is determined by a rational value coefficients of a real polynomial extended to an octonionic polynomials, whose "root" is the space-time surface in M^8. The n roots of a real polynomial would determine a 4-D region in M^8 and its image in $H = M^4 \times CP_2$ would be interpreted as space-time surface.

4. There is a variant of holography, which gives up the full determinism of classical field equations and gives rise to what look like classical topological analogs of Feynman diagrams.

   (a) Consider first the particle level at the level of H. Particle lines generalized to 4-D orbits of 3-D surfaces representing particles. Particles as 4-D orbits of 3-surfaces contain light-line 3- D orbits of partonic 2-surfaces.

   (b) Partons as building bricks of particles in the information theoretic sense, and correspond to partonic 2-surfaces at which the orbits of partonic 2-surfaces meet. Their orbits are 3-D light-like surfaces at which the signature of the induced metric of the space-time surface changes.

   The partonic 2-D surfaces defining topological vertices belong to the 3-D sections of space-time surface with a constant value of M^4 time coordinate t to which one can map the 6-D brane-like entities of M^8 predicted by $M^8 - H$ duality [**?**]

   This picture suggests that, besides the data at the boundaries of CD, also the data at the partonic 2-surfaces in the interior of CD are needed. This failure of classical determinism brings in the failure of the strongest form of holography. There would be a large number of PEs connecting the 3-surfaces at the ends of CD and they would correspond to the analogs of Feynman diagrams.

   Zero energy state as a scattering amplitude would be a superposition over these diagrams. This superposition would not be however pre-determined as in the path integral but the zero energy state would define the superposition of paths in question.

5.2.2 Is the failure of classical determinism possible?

The possibility of classical non-determinism is suggested by the interpretation of space-time surfaces as generalized Feynman diagrams. These Feynman diagram entities would not however define an analog of path integral in TGD framework. Classical non-determinis would be a space-time correlate for the non-nondetermism at quantum level.

In this framework partonic 2-surfaces or equivalently the 3-D sections of the space-time surfaces with constant value of M^4 time would act as 3-surfaces at which the deterministic time evolution as a minimal surface would fail.

Another option is that light-like 3-surfaces containing the partonic 2-surfaces at very special moments of M^4 time define frames. These special values $t = t_n$ of M^4 time would be associated with 6-D branes predicted by M^8 picture as universal special solutions and their images in H would define "very special moments in the life of self" defined by the sequences of SSFRs defining the self.

1. The first hint comes from the dynamics of soap films. Soap films are minimal surfaces. The soap films spanned by 1-D frames consist of minimal surfaces glued together at the frames and this dynamics is non-deterministic in the sense that it allows several soap film configurations due to the different branchings at frames. At frames the minimal surface equations fail.

2. In TGD framework space-time surfaces as PEs are both minimal surfaces and extremals of Kähler action. In this case the 3-surfaces associated with "very special moments of time" $t = t_n$ could define an analog of a dynamically generated frame defining a 4-D soap film. The 3-surfaces at the ends of the CD would be fixed frames like those for soap films.

   This realizes quantum criticality in the sense that the field equations outside frame do not involve the parameters of the action which sum of volume term and Kähler action. The interpretation as a non-linear analog of massless free field theory outside the frame conforms with the basic spirit of quantum field theory. These solutions of field equations rely on a a generalization of holomorphy to 4-D situation so that field equations reduce to purely algebraic conditions involving only the first derivatives of embedding space coordinates. The analogy is defined by the solution of 2-D Laplacian equation in terms of real or imaginary part of an analytic function.

   Field equations consist of two terms, which are divergences for the conserved currents (4-momentum currents plus color currents) defined by the induced metric in the case of volume term. In the interior of the space-time surface these divergences vanish separately for the volume term and Kähler action but not at the frame.

3. The field equations must hold true also at the 3-D frame but this need not be true for both volume term and Kähler action separately. The coupling parameters of the theory make themselves visible only via the frame. For the volume action the divergences of the conserved currents are orthogonal to the space-time surface. For K "ahler action, the divergences of the conserved currents contain to terms. The first term is proportional to the energy momentum tensor of Kähler action and orthogonal to the space-time surface.

   Second term is not orthogonal to the space-time surface. For twistor lift the Kähler also has an M^4 part with a similar decomposition.

   The sums of the parts of divergences orthogonal to the space-time surface and parallel to it must sum up to zero separately. This gives 8 conditions altogether so that the number of field equations is doubled at the frame.

4. Could it happen that the divergences of these two isometry currents are singular and proportional to 3-D delta function but that their sum vanishes and conservation laws are respected? The part of the frame in the space-time interior would be dynamically generated whereas the part of the frame at the ends of CD would be fixed.

5. The restriction to 3-D frames is not the most general option. The delta function singularities could be located also at 2-D partonic 2-surfaces, at light-like 3-surfaces at which the induced metric changes its signature, and at string world sheets which connect these light-like 3-surfaces and have 1-D light-like boundaries at them. The light-like 3-D surfaces would be analogs of the cuts for analytic functions. Partonic 2-surfaces at the ends of light-like 3-surfaces could be analogs for the ends of the cuts. String world sheets could serve as analogs of poles.

6. The non-determinism associated with the soap films and with frames suggests that there is a large number of 4-D "soap films with a given frame", which is fixed at the boundaries of CD but not in the interior of CD.

5.3 Questions related to the theory of consciousness

At the level of TGD inspired theory of consciousness theory, causal diamond (CD) defines a correlate of self or of its perceptive field. CD has sub-CDs which correspond to subselves experienced by self as mental images [L35, L51].

Concerning the evolution of self, the basic notions of "small" state function reduction (SSFR) as an analog of "weak measurement" and "big" SFR (BSFR) as an analog of ordinary SFR.

1. The first deviation from the standard ontology is that BSFR changes the arrow of time defined by the selection of PB of CD at which 3-D part of zero energy states remains unchaged during SSFRs.

2. The second deviation is that either boundary of CD and states at it remain unaffected in SSFRs whose sequence defines self as a conscious entity. This is the TGD counterpart for the Zeno effect of ordinary quantum theory in which repeated measurements of the same observable leave the state unaffected.

The details of the evolution of self are not fully understood and the proposed general view can be criticized.

1. How the constraint that sub-CD serves as a correlate for a classical perceptive field can be taken into account?

2. What is the precise definition of mental images as subselves? Are they at some special positions inside space-time surface?

3. What are the precise definitions of memories and conscious memory recall? The same question applies to the notions of intention, anticipation and attention.

4. Can the mental images be destroyed or do they only experience BSFR and continue to live with an opposite arrow of time and become unconscious to self? If a mental image can completely disappear, what could be the physical mechanism leading to its disappearance?

5. One can challenge the detailed picture of the notion of time evolution by SSFRs. The assumption about the drift of mental images towards future in the second half-cone of CD is ad hoc. Should it be replaced with a deeper assumption. Could one simply assume that they are stationary.

5.3.1 Three ontological options

The basic problem of ZEO is whether the causal diamond (CD) represents a perceptive field in the sense that the space-time surface continues outside the CD or whether CD is an independent entity in the sense that space-time surfaces do not continue outside CD. Conservation laws do not exclude either option.

ZEO allows 3 ontological options which might be called easter, western, and intermediate views.

Option I: Space-time surfaces are restricted inside CDs. Quantum universe is a collection of CDs containing space-time surfaces, which have ends at the boundaries of CD.

In this framework, space-time in cosmological scales is an idealization and could be perhaps explained in terms of the correlations between CDs. CDs do not form a fractal atlas of something unless one says that the atlas *is* the territory. CD is an independent entity rather than a perceptive field of sub-self.

One can argue that for sub-CDs this picture is problematic since it seems that one loses totally the notion of objective reality as something existing outside CD. There are no sensory perceptions. Could the overlaps with other CDs create the experience about the existence of the external world?

Cosmology would be a mental construct and correspond to a very large CD. One would have a multiverse but only at the level of conscious experience. Option I is consistent with the eastern view that only subjective experience exists but not with the western view.

Option II: Space-time surface continues always outside all CDs and CDs can be interpreted always as perceptive fields. Option II conforms with the westerm option and implies that cosmology is something real.

Option III: Self is a hierarchy of CDs such that for sub-CDs the space-time surfaces continue outside the CD but for the largest CD this would not be the case. Sub-CDs would represent perceptive fields but the largest CD would be a God-like entity experiencing itself as the entire cosmos.

Meditators report altered states of consciousness in which the separation to self and external world ceases and the mind is empty. Also the experience of timelessness is mentioned. Could these states correspond to experiences without mental images (sub-CDs) created by SFRs at this highest level?

Option III is roughly consistent with both western and eastern views about consciousness. If one requires the notion of the external world as objective reality and accepts the proposed explanation of altered states of consciousness, option III remains the only possible option.

5.3.2 A general picture about the dynamics of sub-CDs

The ZEO based view of quantum measurement theory and the theory of consciousness inspired by it have not been precisely formulated for sub-CDs. In particular, the question of how sub-CDs as mental images are created, has remained unanswered.

The following proposal provides such a formulation and is consistent with Options I and III.

1. CDs form a fractal atlas of conscious maps but the map would be the territory since in general the space-time surfaces need not continue outside the CD. There would be no external particles as 4-D lines for generalized Feynman diagrams outside CD.

2. Sub-CDs correspond to mental images of CD as a conscious entity. From the point of view of consciousness theory, there are only experiencers (CDs) which can have experiences as mental images (have sub-CDs), be mental images of experiencers (be sub-CDs) and share mental images (intersecting CDs with common sub-CDs).

3. Consistency conditions for the quantum dynamics of CDs and sub-CDs and for the overlapping CDs give rise to correlations between the regions of the map. The shared regions are geometrically analogs for the intersections of the intersections of a covering of a manifold by open sets.

4. For sub-CD the interpretation of sub-CD as a perceptive field would be natural.

The first question is what does one really mean with sub-CD at the level of space-time surfaces.

1. Do the space-time surfaces of sub-CD continue outside sub-CD as space-time surfaces of CD? Does this imply that the quantum dynamics of sub-CDs in ZEO is completely dictated by that of CD? This is certainly not the case. Fermionic zero energy states associated with the sub-CD are possible and are analogous to quantum fluctuations. Note that in the TGD framework all elementary particles can be constructed from fundamental fermions (quarks).

2. If the PE (PE) property fixes completely the space-time surface, its intersections with the boundary of CD, this seems to be the case. If the classical dynamics is not completely deterministic, as suggested by the analogy with minimal surfaces spanned by frames, the situation changes.

   Sub-CD defines a subsystem of CD with boundary conditions at the boundary of CD which do not completely fix the quantum dynamics of sub-CD. Quantum states as WCW spinor fields inside sub-CD could change in SFRs of sub-CD.

   The tensor product of sub-CD with CD would not be ordinary tensor product but much more restricted one and Connes tensor product, related to inclusions of HFFs, would be a possible identification. A sub-system would be like an included hyper-finite factor of type II_1 (HFF).

Suppose that the classical dynamics is indeed non-deterministic and sub-CDs are defined in the proposed manner. How the view about WCW spinor fields changes as one restricts the consideration to sub-WCW.

1. The failure of the classical determinism forces to replace each 3-surface at PB with a discrete tree-like structure consisting of all PEs connecting it to AB. Sub-WCW as the space of PEs is larger than the space of 3-surfaces X^3 at PB. Zero energy states are defined in this sub-WCW and assign to a given X^3 a wave function in this discrete set allowing interpretation as wave function in a set of paths of the tree.

   One cannot avoid the association with cognitive representations of adelic physics involving the number theoretic degrees of freedom characterized by Galois group of the extension of rationals associated with the polynomial defining the space-time region [L9, L45].

2. The activation of sub-WCW would mean an SFR selecting in WCW of CD such sub-WCW for which the space-time surfaces are such that their ends at sub-CD are fixed. This would correspond to SFR creating a sub-CD and corresponding mental image. This would answer the long standing question whether and how mental images can appear as if from scratch.

This SFR would also represent a third kind of SFR having interpretation as a partial localization in WCW associated with CD. This also suggest that mental images could disappear suddenly. This "activation" could be seen as a directed attention.

3. WCW degrees of freedom at the boundaries of sub-CD are fixed. Also sub-WCW spinor fields make sense. One can allow the tensor product of Fock spaces of many-fermion states associated with the boundaries of CD. One would have a QFT like picture with sub-WCW degrees of freedom fixed at boundaries of sub-CD.

4. The tensor product of fermionic state spaces at the boundaries of sub-WCW makes sense and one can define zero energy states in the same manner as proposed hitherto. The only difference is that WCW degrees of freedom are frozen at the boundaries of sub-CD. At the level of conscious experience this means that the subself experiences the external world as fixed. This would be by definition the meaning of being subself.

   The fermionic Fock state basis has an interpretation as a Boolean algebra so that fermionic zero energy states have an interpretation as Boolean statements of form $A \to B$. This would mean that consciousness of the subself would be Boolean, cognitive consciousness, thinking. This conforms with the Eastern view that ordinary consciousness is essentially thinking and that the higher level of consciousness as that associated with the highest level of the CD hierarchy of self is pure consciousness. Thinking assignable to the fermionic degrees of freedom would be seen as an endless generation of illusions. "Reality" in this interpretation would correspond to WCW degrees of freedom.

What restrictions must one pose on the quantum dynamics of CDs in the case of sub-CDs? Does the subjective evolution of sub-CD states by SSFRs and BSFRs make sense for sub-CDs?

1. The increase of the size of sub-CD makes sense and the proposed subjective evolution by scalings and SSFRs makes sense. The time evolution is also now induced by the increase of the perceptive field of a subself defined by the WCW associated with increasing sub-CD bringing in new 4-surfaces due to the classical non-determinism.

2. What about the interaction between CD and sub-CDs. Does this time evolution respect the condition that the space-time surfaces meet the fixed 3-surfaces at boundaries of sub-CD or is it possible that the SSFRs of CD destroy the subself by delocalization so that sub-CD as a mental images must be regenerated by localization in WCW.

3. Also the interaction between overlapping CDs and the sharing of mental images can be understood in this framework.

5.4 Comparison of the revised view of self with the earlier one

The revised view about TGD inspired theory of consciousness relies on the definition of subself at the level of WCW unlike the older view. In the following the new view is compared with the old view.

5.4.1 The view about SSFRs

Earlier picture

The earlier view about SSFRs was inspired by the M^8 picture.

1. The dynamics was assumed to involve both scaling of CD with respect to either tip of CD. The lower half-cone was only scaled whereas the upper half-cone was also shifted as required by the stationarity of the passive boundary. Dynamics at PB was passive in the sense that only a portion of the space-time surface became visible making also new states visible at it (Zeno effect) in the sequence of SSFRs . The idea about scaling leads to a rather concrete proposal for the S-matrix characterizing the scalings of CD.

2. The surfaces inside CD (or sub-CD) were assumed to be mirror symmetric with respect to the middle plane of CD. This assumption does not conform with the assumption that these surfaces define a perceptive field in the sense that they are parts of large space-times and continue outside CD.

The old view had several ad hoc features.

1. The creation of mental images was implicitly assumed without specifying what this could mean mathematically. These mental images were assumed to be created in the upper half-cone just above the $t = T$ mid-plane of CD and shift to the geometric future with the upper half-cone of CD. The asymmetry between upper and half-cone could be seen as reflecting geometrically the future-past asymmetry but was ad hoc.

2. One can criticize the assumption that the memories about the events of the subjective past are located in the geometric future with respect to the mid-plane of CD.

3. Whether mental images can disappear or only die and reincarnate by BSFR, was not specified.

New picture
In the new picture the situation is the following.

1. Also in the new picture, the time evolution by SSFRs would be a sequence of scalings of CD. The assumption about reflection symmetry of space-time surfaces is given up since it is inconsistent with the identification of sub-CD as a perceptive field. Also now the time evolution is passive in the sense that only a new portion of the space-time surface extending outside sub-CD is revealed at each step.

2. As in the previous picture, new discrete WCW degrees of freedom appear during the sequence of SSFRs and complexity increases. For both options only fermionic degrees of freedom remain if full determinism is assumed and if QCC is required also at the level of SFRs.

3. In the new view both directed attention, memory, and intention correspond to a generation of sub-CD by a localization in WCW fixing a subset of 3-surfaces at the PB of CD. Redirecting of attention would allow apparent movement of the sub-CD in the interior of CD and as a special case shifting the mental images in the time direction assumed in the earlier picture.

4. In the new view the loci of mental images are naturally associated with the loci of classical non-determinism that is 3-surfaces at the 4-D minimal surface branches.

5. $M^8 - H$ duality suggests that the branchings occur at H image points of the M^8 cognitive representation defined by the quark momenta which are algebraic integers for the extension of rationals defined by the polynomial defining $X^4 \subset M^8$. The non-determinism at $X^4 \subset H$ point set would correspond to non-determinism assignable to a bound state of quarks at corresponding point of M^8.

   Note that physical states correspond to total quark momenta which are rational integers, one can speak of Galois confinement meaning that physical states are Galois singlets. This gives an infinite hierarchy of bound states formed by a universal, purely number theoretical mechanism. All bound states could be formed in this manner.

   The non-determinism at $X^4 \subset H$ point which corresponds to a subset of points as images of quark momenta composing the bound state would correspond to non-determinism assignable to a bound state of quarks at corresponding point of M^8. There would be a hierarchy of CDs within CDs and hierarchy of mental images corresponding to the hierarchy of bound states.

   The bound state momenta are mapped to $X^4 \subset H$ by $M^8 - H$ duality already described. In particular, the positions of quarks contained in 6-branes X^6 with a constant energy $E = E_n$ are mapped to a sequence of points at the boundary of cd of the system by M^8-duality and it can be said to represent the positions of these quarks. These point sets define sequences of "very special moments in the life of self".

   The targets of attention would therefore form a discrete set assignable to bound states of quarks and antiquarks. Note however that each 3-surface X^3 in the superposition defining the WCW spinor field at the PB of CD has its own discrete set loci of non-determinism. BSFRs can change the superposition of these 3-surfaces. The selection between branches is possible in BSFR but not in SSFRs.

6. An attractive idea motivated by ZEP is that volitional action could be interpreted in the new view as an SFR selecting one path at the node of a tree characterizing the non-determinism. Single deterministic time evolution analogous to a computer program would be selected rather than modifying the deterministic time evolution as in standard ontology. In the M^8 picture, the very special moments $t = r_n$ in the life of self correspond to the roots of a real polynomial. What happens when all roots have been experienced? Does NMP force the BSFR to occur since nothing new can be learned?

5.4.2 Comparison of the views about BSFR

Those aspects of BSFR in which old and new views differ are of special interest.

Earlier view

The fact that the notion of sub-CD and mental image were not properly formulated led to several ad hoc assumptions.

1. The possible failure of a strict determinism was realized. The failure of strict determinism was assigned to "very special moments in the life of self" associated with the images $E = E_n$ planes of $M^4 \subset M^8$ at which the partonic vertices as loci of non-determinism were assigned.

2. The mental images of previous life near the AB of CD were assumed to be inherited as "silent wisdom". Their contents was from the early period of life with opposite arrow of time and one can of course ask whether they were really "wisdom".

3. There were also assumptions about the change of the size scale of CD in BSFR. The idea that the reduction of the size scale guarantees that re-incarnate has childhood was considered. This assumption also prevents unlimited increase of the size scale of sub-CD.

New view

The new view makes it possible to develop a more detailed picture of what happens in BSFR.

1. The WCW localization at the AB of CD selects one of the branches of the space-time surface beginning at the PB. This selection of the branch happens to each 3-surface in the superposition of 3-surfaces at the PB defined by the WCW spinor field before BSFR.

2. The future directed tree becomes a past directed tree beginning from one particular branch at the AB. The initial and final space-time surface share a common space-time surface connecting the roots of the old and new trees. This is essential for having a non-trivial transition amplitude for BSFR at WCW level.

In the earlier view, the mental images interpreted as memory mental images and located near the boundary of CD were assumed to be inherited as "silent wisdom" by the time-reversed reincarnate. What happens now?

The notion of "silent wisdom" as inherited information still makes sense.

1. The new space-time surfaces originate from 3-surface which was selected by WCW localization in BSFR. Therefore the new space-time surfaces carry classical information about previous life.

2. The space-time surfaces originating from the new root are near to the space-time surface connecting the old and new roots. The WCW spinor field before and after BSFR musthave a strong overlap in order to make the transition amplitude large. This implies that information about previous life is transferred to the new life.

3. The nearness property could imply that they are easily re-created as perceptions by directed attention so that they would indeed be "silent" wisdom. These mental images are from the later part of the life cycle rather than from the early life as in the earlier picture. If aging means getting wisdom, then silent wisdom would be in question.

Does the notion of "silent wisdom" as mental images make sense?

1. Mental images - this includes both sensory and memory mental images and intentions) are naturally assignable to the loci of classical non-determinism at the images of the planes $E = E_n$ of the branched space-time surfaces associated with the new root ("very special moments in the life of self").

   For the special space-time surface connecting the roots of old and new space-time surface, the surfaces $E = E_n$ in M^8 would not change and the mental images would carry information about previous life. Could one talk about potentially conscious "silent wisdom".

2. What happens to the mental images of self in BSFR? Can they be preserved or do they disappear or do they reincarmate by BSFR? The idea about preservation makes sense only for space-time surfaces connecting the roots.

3. What can happen to the size scale of CD in BSFR? The extreme option that CD decreases in size by shift of the formerly PB such that the time evolutions are fully determinimistic in the superposition of 3-surfaces. There would be no inherited silent wisdom and the self would start from scratch, live a chilhood. Otherwise these loci would define candidate for inherited silent wistom.

In the earlier picture the mental images corresponding to sub-CD could not disappear although it could die by BSFR and reincarnate with a reversed arrow of time. Can the mental image disappear now? Creation of mental image require metabolic energy feed: this explains 7 ± 2rule for the number of simultaneous mental images. Could this happen when attention is redirected? Therefore one could argue that mental image must totally disappear when the attention is redirected.

On the other hand, time reversed mental image apparently feeds energy to the environment in the original arrow of time, i.e. apparently dissipates. Could this dissipation be interpreted as an energy feed for its time reversal.

Note that the total disappearance of the mental image means delocalization at the level of WCW and seems possible. The new view clearly challenges the idea about the Karma's cycle of self. This cycle appears in many applications of BSFR.

5.5 Conclusions

Also the article *Some comments related to Zero Energy Ontology (ZEO)*" [L35] written for few years ago challenged the basic assumptions of ZEO. One tends to forget the unpleasant questions but now it was clear that it is better to face the fear that there might be something badly wrong. ZEO however survived and several ad hoc assumptions were eliminated.

5.5.1 Progress at the level of basic TGD

The basic goal is to improve the understanding about quantum-classical correspondence. The dynamics of soap films serves as an intuitive starting point.

1. In TGD frame 3-surfaces at the boundaries of CD define the analog of frame for a 4-D soap film as a minimal surface outside frame. This minimal surface would be an analog of a holomorphic minimal surface and simultaneous exremal of Kähler action except at the frame where one would have delta function singularities analogous to sources for massless d'Alembert equation.

2. There is also a dynamically generated part of the frame since the action contains also Kähler action. The dynamically generated parts of the frame would mean a failure of mimimal surface property at frame and also the failure of complete determinism localized at these frames.

3. At the frame only the equations for the entire action containing both volume term and Kähler term would be satisfied. This guarantees conservation laws and gives very strong constraints to what can happen at frames.

   The frame portions with various dimensions are analogous to the singularities of analytic functions at which the analyticity fails: cuts and poles are replaced with 3-, 2-, and 1-D

singularities acting effectively as sources for volume term or equvavelently Kähler term. The sum of volume and Kähler singularities vanish by field equations. This gives rise to the interaction between volume and Kähler term at the loci of non-determinism.

4. H-picture suggests that the frames as singularities correspond to 1-D core for the deformations of CP_2 type extremals with light-like geodesic as M^4 projection, at partonic 2-surfaces and string world sheets, and at 3-D $t = t_n$ balls of CD as "very special moments in the life of self" which integrate to an analog of catastrophe. T

   Deformations of Euclidean CP_2 type extremals, the light-like 3-surfaces as partonic orbits at which the signature of the induced metric changes, string world sheets, and partonic 2-surfaces at $r = t_n$ balls taking the role of vertices give rise to an analog of Feynman (or twistor -) diagram. The external particles arriving the vertex correspond to different roots of the polynomial in M^8 picture co-inciding at the vertex.

The proposed picture at the level of $H = M^4 \times CP_2$ has dual at the level of (complexified) M^8 identifiable as complexified octonions. The parts of frame correspond to loci at which the space-time as a covering space with sheet defined by the roots of a polynomial becomes degenerate, i.e. touch each other.

Concerning the physical interpretation, a crucial step of progress was the interpretation of M^8 as analog of momentum space allowing to interpret $M^8 - H$ duality as an analog of momentum-position duality and of complementarity principle of wave mechanics [L53]. This forced to modify $M^8 - H$ duality in M^4 degrees of freedom to satify the constraints posed by UP.

There is a nice analogy with the catastrophe theory of Thom [A6, A1]. The catastrophe graph for cusp catastrophe serves as an intuitive guide line. embedding space coordinates serve as behaviour variables and space-time coordinates as control variables. One obtains a decomposition of space-time surface to regions of various dimension characterized by the degeneracy of the root.

5.5.2 Progress in the understanding of TGD inspired theory of consciousness

The improved view about ZEO makes it possible to define the basic notions like self, sub-self, BSFR and SSFR at the level of WCW. Also the WCW correlates for various aspects of consciousness like attention, volition, memory, memory recall, anticipation are proposed. Attention is the basic process: attention creates sub-CD and subself by a localization in WCW and projects WCW spinor field to a subset of WCW. This process is completely analogous to position measurement at the level of H. At the level of M^8 it is analogous to momentum measurement.

One can distinguish between the Boolean aspects of cognition assignable to WCW spinors as fermionic Fock states (WCW spinor field restricted to given 3-surface). Fermionic consciousness is present even in absence of non-determinism. The non-determinism makes possible sensory perceptions and spatial consciousness.

A precise definition of sub-CD as a correlate of perceptive field at WCW level implies that the space-time surfaces associated with sub-CDs continue outside it. This gives powerful boundary conditions on the dynamics. For the largest CD in the hierarchy of CDs of a given self, this constraint is absent, and it is a God-like entity in ZEO. This leads to a connection between the western and eastern views about consciousness.

A connection with the minimal surface dynamics emerges [L54]. The sub-CDs to which mental image as subselves are assigned would be naturally associated with portions of dynamically generated frames as loci of non-determinism. If one identifies partonic 2-surfaces as vertices, one can interpret the collection of possible space-time surfaces for a fixed 3-surface at PB as a tree. All paths along the tree are possible time-evolutions of subself. The dynamics of consciousness for fixed 3-surface at PB becomes discrete and provides discrete correlate for a volitional action as selection of a path or a subset of paths in the tree. The reduction of dynamics of mental imagines to discrete dynamics would mean a huge simplification and conforms with the discreteness of cognitive representations.

5.5.3 Challenges

There are many challenges to be faced. The discrete dynamics of sub-self consciousness certainly correlates with the notion of cognitive representation based on adelic physics [L17, L16] and imply-

ing a discretization at both space-time level and WCW level. The Galois group for the extension of rationals acting on the roots of the polynomial plays a key role in this dynamics [L45, L46].

One teaser question remains. Localization requires energy quite generally and this conforms with the fact that mental images demand metabolic energy feed. It is possible to redirect attention and it remains unclear whether the mental image disappears totally or suffers BSFR.

This relates directly to the question whether consciousness continues after the physical death. If mental images (and corresponding sub-CDs) can disappear, the same can happen to us since we are mental images of some higher level self. If this cannot happen, BSFR means death and reincarnation with an opposite arrow of time in a completely universal sense. For instance, sleep period could correspond to a kind of death at some level of the personal self hierarchy generalizing the Id-ego-superego hierarchy of Freud. This would explain why we have no memories of the sleep period.

5.6 Appendix: M^8- and H views about classical non-determinism and particle reactions

5.6.1 M^8 picture and $M^8 - H$ duality

In M^8 picture, space-time surfaces correspond to real projections of 4-D complex "roots" of octonionic polynomials obtained from real polynomials with rational coefficients by algebraic continuation, i.e. by replacing real coordinate by complexified octonion coordinate [L12, L13, L14] [L41, L42]. The interested reader finds a rather detailed summary of $M^8 - H$ duality in Appendix 5.6.

$M^8 - H$ duality maps the point of $M^4 \times E^4$ to a point of $M^4 \times CP_2$ such that the point of $M^4 \subset M^4 \times E^4$ is mapped to some point of $M^4 \subset M^4 \times CP_2$. $M^8 - H$ duality is not a local map. Rather, the normal space of a $x \in X^4 \subset M^8$ goes to a point of CP_2 characterizing its quaternionic normal space.

1. To be a 4-D "root" in the complex sense means that the real part of a complexified octonionic polynomial determining the space-time surfaces vanishes. The number theoretic content of this condition is that the normal space of the space-time surface is quaternionic and therefore associative. The second option would be that the tangent space is associative but this gives only M^4 as a solution.

2. At a given point there are n roots and some of them can coincide in some regions of the space-time surface. These regions correspond to the branchings of the space-time surface at which particle-like entities identified as space-time surfaces meet and interact.

   The quaternionic normal plane at this intersection is not unique so that several CP_2 points of $X^4 \subset H$ correspond to a single point of $X^4 \subset M^8$. The extreme situation is encountered in a point-like singularity when the normal plane at a given point of M^4 is a sub-manifold of CP_2.

   The interpretation is as particle vertices. The intuitive expectation is that they correspond to partonic 2-surfaces and perhaps also string world sheets. These surfaces are mapped to those in $M^4 \times CP_2$ by $M^8 - H$ correspondence.

3. Also 6-D brane like entities are predicted as universal "roots" they correspond to 6-spheres in M^8 with M^4 projection which is a 3-ball with constant value $E = E_n$ of energy as counterpart of the Minkowski time coordinate such that E_n is the root of the real polynomial defining the octonionic polynomial. The momenta $(E_n, p = 0)$ are mapped to points $t_n = (\hbar_{eff}/E_n, 0)$ and define "very special moments of time in the life of self".

   The points with $p \neq 0$, in particular the points corresponding to quark momentum, however correspond to $t < t_n$ at the boundary of cd with size $L(p) = \hbar_{ef}/\sqrt{E_n^2 - p^2}$. To these moments the failure of classical determinism giving rise to one particular kind of quantum non-determinism is concentrated. Note that points of double hyperboloid of M^4 with opposite energies are mapped to opposite boundaries of cd.

4. The intersections of 4-D "roots" with 6-D brane-like entities are 2-D and it might be possible to interpret them as analogs of either partonic 2-surfaces or string world sheets at which

several roots become degenerate of octonionic polynomial co-incide. Outside the singularity, the roots do not coincide and define separate space-time sheets and it is natural to interpret them as external particles of a particle reaction.

5. At the light-like orbits of partonic 2-surfaces the induced metric for the H-image of the space-time surface becomes degenerate since its signature changes. Could one say that the Minkowskian and Euclidean roots coincide at the partonic orbits?

   One can also wonder what the M^8 interpretation of wormhole contacts having two throats could be. Do the two throats correspond to two coincing roots at the level of M^8 having different normal spaces and mapped to separate 2-surfaces in H?

5.6.2 Catastrophe theoretic analogy

Consider the analogy with the catastrophe theory of Thom [A6] in more detail.

1. Catastrophe map is the graph of solutions for the vanishing of the gradient of a potential function as a function of control parameters. One considers only real roots as function of variable control parameters and the number of real roots varies as a function of parameters and one obtains lower-dimensional regions at which the number of roots to catastrophe polynomial changes as roots become degenerate [A6, A1]. Cusp catastrophe serves as the school example.

2. In the recent case, space-time surfaces correspond to roots of complexified octonionic polynomials and the coefficients of the polynomial appear as control parameters. Also complex roots are allowed and real 4-D space-time surface is obtained as a real projection and mapped to H by $M^8 - H$ duality and conjectured to correspond to a preferred extremal of an action determined by the twistor lift of TGD.

3. The basic motivations for this assumption are quantum criticality requiring preferred extremal property, which requires at the level of H the independence of the dynamics on coupling parameters of the twistor lift of Kähler action outside the loci of non-determinism demanded by M^8 level.

5.6.3 Connection between singularities and preferred extremals of various types

The above picture suggests the characterization of the space-time surfaces in terms of their singularities as surfaces of M^8.

At the level of H one can consider 4 kinds of very simple preferred extremals, which give rise to prototype singularities.

1. Einsteinian spacetime $X^4 \subset M^8$ with a 4-D M^4 projection and a unique normal space as a point of CP_2. $X^4 = M^4$ defines a prototype.

2. Cosmic string extremal $X^2 \times Y^2$ with Y^2 a complex surface in CP_2 and defining a set of normal spaces assignable to a point of X^2. $M^2 \times S^2$, S^2 a geodesic sphere defines a proto type. S^2 can be either homological trivial or non-trivial.

3. $X^3 \times S^1 \subset M^4 \times CP_2$, where S^1 is a geodesic circle of CP_2, is a candidate for a preferred extremal and singular surface. Both $M^3 \times S^1$ and $E^3 \times S^1$ are minimal surfaces and vacuum extremals of Kähler action.

   For the Euclidean signature, X^3 could be space-like and define a 3-ball compactifying to S^3 as a sub-manifold of the S^6 brane. The very special moments t_n would be singular in the sense that the normal space at a given point of $X^3 \subset M^4 \subset M^8$ would not be unique and would give rise S^1 singularity.

4. CP_2 type extremal with light-like geodesic as $M^4 \subset H$ projection and corresponding to a light-like geodesic in M^8 with normal spaces forming a 3-D surface in CP_2. Also $M^1 \times Y^3 \subset M^4 \times CP_2$ can be considered but is probably not a preferred extremal.

The intuitive picture is that these 4 types of preferred extremals correspond to singularities of the normal space of $X^4 \subset M^8$ of dimension $d = 0, 1, 2, 4$ and codimension $d_c = 4 - d$.

5.6.4 Analogy with knot theory

In knot theory a knot in 3-D space is projected to 2-plane where one obtains a diagram containing crossings. Knot invariants can be constructed in terms of this diagram. A knot theory inspired intuition is that space-time surfaces near to these special cases are projected to these special surfaces to get the toy model.

1. Canonically embedded $M^4 \subset M^8$ (or $M^4 \subset M^4 \times CP_2$) is an analog of the plane to which the knot is projected. One can project the space-time regions with 4-D $M4$ projection to M^4. In particular, those with a Minkowskian signature of the induced metric.

2. The M^4 projection of CP_2 type extremal is 1-D light-like geodesic. One must project the deformations of CP_2 type extermals to CP_2 type extremal at the level of H. At the level of H, CP_2 type extremal could correspond to a light-like geodesic of M^8 such that each point of the geodesic is singular point such that the union of quaternionic normal spaces defines a 3-D quaternionic surface in CP_2.

   A puncture in E^3 as an infinitesimal hole serves as an analogy. At the puncture, one can say that all normal spaces labelled by points of S^2 are realized.

   At the given point of the light-like geodesic, the quaternionic normal space of point is not unique but a 3-D union of normal spaces and defines a 3-D subset CP_2.

3. For the $X^2 \times Y^2 \subset M^4 \times CP_2$ type cosmic string extremals and their small deformations, one must project to $M^2 \times S^2 \subset CP_2$. For a point of X^2 the normal spaces define $Y^2 \subset CP_2$ so that the singularity is milder.

   For $X^3 \times S^1 \subset M^4 \times CP_2$ the normal spaces at a point of X^3 would define $S^1 \subset CP_2$. If X^3 is Euclidean, these 3-D singularities could correspond to the $t = t_n$ planes associated with the branes. The small deformations of these surfaces would project to $M^3 \times S^1$. This picture would integrate all 3 kinds of singularities and various types of preferred extremals to a single unified picture.

5.6.5 A toy model for the singularities

The following toy model for the singularities in the case of CP_2 type extremals generalizes also to other singularities.

1. A rather general class of CP_2 type extremals can be represented as a map $M^4 \to CP_2$ given by

$$m^k = p^k f(r) \ ,$$

   where p^k is light-like momentum and r is radial $U(2)$ invariant CP_2 coordinate labelling 3-spheres of CP_2 such that $r = \infty$ gives homologically non-trivial geodesic 2-sphere instead of 3-sphere.

   If $f(r)$ approaches constant value for $r \to \infty$, one can say that M^4 time stops at this limit, and one obtains a homologically non-trivial geodesic sphere instead of 3-D surface identifiable as an intersection with 6-D brane. Various external particles of the vertex would correspond to $m^k = p_k f_i(r)$ such that their values at $r = \infty$ co-incide.

   It is not possible to obtainh omologically trivial 2-sphere in this manner.

2. Outside the vertex, the CP_2 type space-time sheets have distinct light-like geodesics as M^4 projections and they can be continued to distinct regions of M^4 in the toy model.

   The analog of the knot diagram would be a set of M^4:s with different constant values of CP_2 coordinates. The CP_2 type extremals would be glued along light-like geodesics to various M^4s.

   The CP_2 points of M^4:s meeting at the same geodesic sphere must belong to the same geodesic sphere S^2. The S^2:s associated with different vertices are different. Note that any two geodesic spheres must have common points.

3. In the toy model for the string world sheets $X^2 \times Y^2$ would be projected to a piece of $M^2 \times S^2$ connecting two partonic vertices with the same S^2. S^2:s would be at the ends of the string, whose orbit is a piece of M^2.

   $B^3 \times S^1$ could be interpreted as a subset of 6-D brane with B^3 identified as the $t = t_n$ cross section of M^4 light-cone.

This picture would suggest that the singularities could be indeed located to $t = t_n$ planes and integrated together to form a rough analog of catastrophe map.

5.6.6 Some examples of minimal surfaces with 1-D CP_2 projection

This subsection is not directly relevant to the basic topic and is added to give ideas about the possible role of volume term.

The original proposal was that preferred extremals are extremals of Kähler action but the twistor lift introduced the volume term as an additional term. This removed the huge vacuum degeneracy of Kähler action meaning that any 4-surface for which CP_2 projection was so called Lagrange manifold with the property that induced Kähler form vanishes, was a solution of field equations. For these surface induced Kähler potential is pure gauge.

The addition of the volume term removes this degeneracy and only minimal surfaces of this kind are possible as extremals. It is however not clear whether they are preferred extremals (are they analogs of complex surfaces?).

These solutions have not been studied previously [K3]. Space-time surfaces representing a warped embedding of M^4 with a flat metric represent the simplest example.

1. Denoting the angle coordinate of the geodesic sphere S^1 byΦ and the metric of S^1 by $ds^2 = -R^2 d\Phi^2$ the ansatz reads in linear Minkowski coordinates as $\Phi = k \cdot m$, where k is analog of four-momentum. The induced metric is flat and the second fundamental form vanishes by the linearity of Φ in m so that the field equations are satisfied.

   Boundary conditions require the vanishing of the normal components of momentum currents and give $(\eta^{\alpha\beta} - R^2 p^\alpha p^\beta) n_\beta = 0$ .This condition cannot be satisfied so that these solutions should have infinite size, which looks unphysical.

   The presence of the volume term in the action implies that the induced metric appears in the boundary conditions and this represents a problem quite generally. The only way to overcome the problem is that there are no boundaries. The many-sheetedness indeed makes this possible.

   The warped extremals could represent a reasonable approximation of the space-time surface in the regions which are almost empty.

2. The light velocity defined in terms of time taken to get from the M^4 position A to B, is reduced to $c_1 = \sqrt{1 - |k \cdot k|}$. If k is light-like this does not happen.

   Although the analog of gravitational force is vanishing in warped metric, the deviation the flat metric from M^4 metric given by $|k \cdot k|$ in flat case could it be interpreted as gravitational potential and the gravitational potential energy of test mass would be given by by $E_{gr} = -m|k \cdot k|$.

   Could Nature provide a kind of cognitive representation or toy model of a gravitational field as a piecewise constant function in terms of CDs with which warped vacuum extremals would be associated? The representation would contain length scale dependent Λ as second parameter assigning momentum 4-momentum proportional to $\Lambda\, p^k$ to the CD. The volume energy would include its gravitational potential energy represented in terms of warping?

   For warped solutions the space-time light cone - to be distinguished from its embedding space counterpart - would be defined by $c_1^2 t^2 - r^2 = 0$ and space-time CD would be modified accordingly.

Only single extremal - canonically embedded M^4 - remains from the spectrum of cosmological vacuum extremals for Kähler action having 1-D CP_2 projection and defined by $\Phi = f(a)$, where f is an arbitrary function of light-cone proper time coordinate $a = \sqrt{t^2 - r_M^2}$.

At QFT-GRT limit, the many-sheeted space-time is approximated with Einsteinian cosmology with the deviation of the induced metric from M^4 metric defined by the sum of the corresponding deviations for the sheets. Since the value of Λ becomes large in short p-adic length scales, a cosmology resembling GRT type cosmology could emerge and Einstein's equations would be a remnant of Poincare symmetry.

The induced metric for the solutions has very little to do with the metric appearing at the Einsteininian limit. The models of cosmology as space-time surfaces based on Kähler action with vanishing Λ could however make sense in very long scales for which Λ approaches zero.

For string dominated cosmology, the comoving mass is proportional to a [K23, K3, K16]. One has a silent whisper amplified to a Big bang in GRT sense. Also critical cosmology [K3] as an analog of inflationary cosmology for which curvature scalar as dimensional quantity vanishes can be regarded as a silent whisper amplified to a Big Bang and also it becomes Euclidean for a critical value $a = a_0$ of cosmic time.

6 What could 2-D minimal surfaces teach about TGD?

In the quantum TGD based on zero energy ontology (ZEO) space-time surfaces within causal diamonds (CDs) are fundamental objects [L35, L52]. $M^8 - H$ duality plays a central role: the earlier views can be found in [L12, L13, L14] and the recent view in [L41, L42, L50] differing in some aspects from the earlier view. $M^8 - H$ duality means that one can interpret the space-time surfaces in two ways: either as an algebraic surfaces in complexified M^8 or as minimal surfaces in $H = M^4 \times CP_2$ [L52]. $M^8 - H$ duality maps these surfaces to each other.

The twistor lift of TGD is another key element [K22, L24]. It replaces space-time surfaces with their 6-D twistor spaces represented as 6-D surfaces in the product of twistor spaces assignable to M^4 and CP_2 and having an induced twistor structure. This implies dimensional reduction of a 6-D Kähler action to a sum of a 4-D Kähler action and volume term having interpretation in terms of cosmological constant Λ. Kähler structure exists only for the twistor spaces of M^4 and CP_2 [A2] so that the theory is unique.

Each extension of rationals (EQ) corresponds to a different value $\Lambda > 0$. For $\Lambda = 0$, the finite-D extension of rationals determined by real polynomials would be replaced with real analytic functions or subset of them.

Whether $\Lambda = 0$ can be accepted physically, will be one of the key topics of this article. At the level of adelic theory of cognition [L17, L15] this question boils down to the question whether cognition is always finite and related to finite-D extensions of rationals of whether also infinite-D extensions and transcendence can be allowed.

6.1 Basic notions

$M^8 - H$ duality and twistor lift of TGD are the basic notions relevant for what follows and its is appropriate to discuss them briefly.

6.1.1 Space-time surfaces at the level of M^8

The recent view of $M^8 - H$ duality [L41, L42, L50] deserves a brief summary.

At M^8 level, space-time surfaces can be regarded as algebraic 4-surfaces in complexified M^8 having interpretation as complexified octonions. The dynamical principle states that the normal space of the space-time surface at each point is associative and therefore quaternionic. The space-time surfaces are determined by the condition that the real part of an octonionic polynomial obtained as an algebraic continuation of a real polynomial with rational coefficients vanishes.

This gives a complex surface which is minimal surface from which one takes a real part by projecting to real part of complexified M^8: it is not clear whether it is minimal surface of M^8. Minimal surface property is the geometric analog of a massless d'Alembert equation [L5, L29].

Also real analytic functions can be considered [L41, L42] but this leads to infinite-D extensions of rationals in the adelization requiring that also the p-adic counterparts of the space-time surfaces exist. Whether this phase which would correspond to $\Lambda = 0$, can be accepted physically, will be one of the key topics in the sequel.

The conditions defining the space-time surfaces are exactly solvable and the conjecture is that these surfaces are minimal surfaces by their holomorphy (the induced metric of the space-time surface does not however play any role and its role is taken by the complexification number theoretic octonion norm which is real valued for the real projections) [L41, L42, L50].

6.1.2 Space-time surfaces at the level of $H = M^4 \times CP_2$

At the level of $H = M^4 \times CP_2$, space-time surfaces are preferred extremals (PEs) of a 6-D Kähler action fixed by the twistor lift of TGD [L24]. The existence of the twistor lift makes TGD unique since only the twistor spaces of $T(M^4)$ and $T(CP_2)$ have the needed Kähler structure [A2]. The 6-D twistor space $T(X^4)$ of the space-time surface X^4 is represented as a 6-surface X^6 in $T(M^4) \times T(CP_2)$. $T(X^4)$ has S^2 as fiber and X^4 as base. The twistor structure of $T(X^4)$ is induced from the product of twistor structures of $T(M^4)$ and $T(CP_2)$. The S^2 bundle structure of X^6 requires dimensional reduction and dimensionally reduced 6-D Kähler action consists of a volume term having an interpretation in terms of length scale dependent cosmological constant Λ and 4-D Kähler action.

Physically "preferred" means holography: to a given 3-surface at the either boundary of CD one can assign a unique space-time surface as an analog of Bohr orbit. This assumption is very probably too strong: the number of Bohr orbits is finite and the dynamically determined frames of the space-time surface would characterize the non-determinism [L52]. "Preferred" has several mathematical meanings, which are conjectured to be equivalent.

One of those meanings is that space-time surfaces simultaneous extremals of both volume term and Kähler action and field equations reduce almost everywhere to the analogs of the conditions satisfied by complex surfaces of complex manifolds. Note that the field equations express local conservation laws for the isometries of $H = M^4 \times CP_2$ and are in this sense hydrodynamic.

The field equations for preferred extremals do not depend on coupling parameters. This expresses quantum criticality and reduces the number of solutions dramatically as required by the fact that at the level the field equations are algebraic rather than differential equations.

Space-time surfaces are therefore minimal surfaces everywhere except at singularities, which are lower-dimensional surfaces. At singularities they are satisfied only for the entire action. The divergences of the isometry currents for the volume term and Kähler action would have delta function singularities, which must cancel each other to guarantee conservation laws.

The singular surfaces can be wormhole throats as boundaries of CP_2 type extremals at which the signature of the induced metric changes, partonic 2-surfaces acting as analogs of vertices at which light-like partonic orbits representing the lines of generalized Feynman (or twistor) diagram meet, and string world sheets having light-like boundaries at partonic orbits.

Also 3-D singularities are predicted and could be associated to time= constant hyperplanes of M^4, which in M^8 picture are associated with the roots of the polynomials determining space-time region: I have christened these roots "very special moments in the life of self" [L28]. The roots define 6-spheres as universal special solutions and they intersect future light-cone along $t = r_n$ hyper-plane. It is possible to glue different solutions together along these planes so that they can serve as loci of classical non-determinism.

The singular surfaces are analogous to the frames of soap films [L52]: part of them are fixed and at the boundaries of CD and part of them are dynamically generated. Classical conservation laws for the isometry currents expressing field equations pose strong conditions on what can happen in vertices.

6.1.3 $M^8 - H$ correspondence for the singularities

By $M^8 - H$ correspondence, the singular surfaces of $X^4 \subset H$ correspond to the singularities of the pre-image at the level of M^8. For the singularities $X^4 \subset M^8$ the quaternionic normal space of X^4 is not unique at points of a $d < 4$ dimensional surface but is replaced with a union of quaternionic normal spaces labelled by the points of sub-manifold of CP_2 for which the dimension is $d_c = 4 - d$. At the level of H, the singular points blow-up to d_c-dimensional surfaces. What happens for the normal space at a puncture of 3-space serves as a good analog.

In particular, the deformation of a CP_2 type extremal as a singularity corresponds to an image of a 1-D singularity with $(d = 1, d_c = 3)$ and $d_c =$ 3-dimensional blow up. The properties of

CP_2 type extremals suggest the 1-D curve is light-like curve for mere Kähler action and light-like geodesic for the Kähler action plus volume term.

These situations correspond to $\Lambda = 0$ and $\Lambda > 0$, where Λ is length scale dependent cosmological constant as coefficient of the volume term of action.

6.1.4 Membrane like structures as particularly interesting singularities

Membrane-like structures appear in all length scales from soap bubbles to large cosmic voids and it would be nice if they were fundamental objects in the TGD Universe. The Fermi bubble in the galactic center is an especially interesting membrane-like structure also from the TGD point of view as also the membrane- like structure presumably defining the analog of horizon for the TGD counterpart of a blackhole. Cell membrane is an example of a biological structure of this kind. I have however failed to identify candidates for the membrane-like structures.

An especially interesting singularity would be a static 3-D singularity $M^1 \times X^2$ with a geodesic circle $S^1 \subset CP_2$ as a local blow-up.

1. The simplest guess is a bubble-like structure as a product $M^1 \times S^2 \times S^1 \subset M^4 \times CP_2$. The problem is that a soap bubble is not a minimal surface: a pressure difference between interior and exterior of the bubble is required so that the trace of the second fundamental form is constant. Quite generally, closed 2-D surfaces cannot be minimal surfaces in a flat 3-space since the vanishing curvature of the minimal surface forces the local saddle structure.

2. A correlation between M^4 and CP_2 degrees of freedom is required. In order to obtain a minimal surface, one must achieve a situation in which the S^2 part of the second fundamental form contains a contribution from a geodesic circle $S^1 \subset CP_2$ so that its trace vanishes. A simple example would correspond to a soap bubble-like minimal surface with M^4 projection $M^1 \times X^2$, which has having geodesic circle S^1 as a local CP_2 projection, which depends on the point of $M^1 \times X^2$.

3. The simplest candidate for the minimal surface $M^1 \times S^2 \subset M^4$. One could assign a geodesic circle $S^1 \subset CP_2$ to each point of S^2 in such a way that the orientation of $S^1 \subset CP_2$ depends on the point of S^2.

4. A natural simplifying assumption is that one has $S^1 \subset S^2_1 \subset CP_2$, where S^2_1 is a geodesic sphere of CP_2 which can be either homologically trivial or non-trivial. One would have a map $S^2 \to S^2_1$ such that the image point of point of S^2 defines the position of the North pole of S^2_1 defining the corresponding geodesic circle as the equatorial circle.

   The maps $S^2 \to S^2_1$ are characterized by a winding number. The map could also depend on the time coordinate for M^1 so that the circle S^1 associated with a given point of S^1 would rotate in S^2_1. North pole of S^2_1 defining the corresponding geodesic circle as an equatorial circle. These maps are characterized by a winding number. The map could also depend on the time coordinate for M^1 so that the circle S^1 associated with a given point of S^1 would rotate in S^2_1.

   The minimal surface property might be realized for maximally symmetric maps. Isometric identification using map with winding number $n = \pm 1$ is certainly the simplest imaginable possibility.

Large voids of size scale or order 10^8 light years forming honeycomb like structures are rather mysterious objects, or rather non-objects. The GRT based proposal is that the formation of gravitational bound states leads to these kinds of structures in general relativity but I do now know how convincing these arguments really are.

One should answer two questions: what are these voids and why do they form these lattice-like structures?

One explanation of large voids is based on the TGD based view about space-time as a 4-surface in $H = M^4 \times CP_2$.

1. Space-time surfaces have M^4 projection, which is 4-D for what I call Einsteinian space-times. At this limit general relativity is expected to be a good approximation for the field theory limit of TGD.

   However, the M^4 projection can be also 3-D , 2-D or 1-D. In these cases one has what looks like a membrane, string, or point-like particle. All these options are realized. The simplest membranes would look like $M^1 \times S^2 \times S^1$, S^1 a geodesic circle of CP_2, which depends on a point of $M^1 \times S^2$ defining the M^4 projection. Only this assumption allows us to have a minimal surface. Varying S^1 creates the analog of pressure difference making soap films possible. I discovered this quite recently although the existence of membrane like entities was almost obvious from the beginning.

   Small perturbations tend to thicken the dimension of M^4 projection to 4 but the deformed objects are in an excellent approximation still 3-D, 2-D or 1-D.

2. Large voids could be really voids in a good idealization! Even 4-D space-time would be absent! The void would be the true vacuum. It should be noticed that matter as smaller objects, say cosmic strings thickened to flux tubes, would in turn have galaxies as tangles, which in turn would have stars as tangles. The TGD counterparts of blackholes would be dense flux tube spaghettis filling the entire volume.

3. What is remarkable that membranes are everywhere: large voids, blackhole horizons, Fermi bubbles, cell membranes, soap bubbles, bubbles in water, shock wave fronts, etc....

What could then give rise to the lattice like structures formed from voids? Here TGD suggests a rather obvious solution.

1. The lattices could correspond to tessellations of the 3-D hyperbolic space H^3 for which cosmic time coordinate identified as light-cone proper time is constant. H^3 allows an infinite number of tessellations whereas Euclidean 3-space allows a relatively small number of lattices.

   There is even empirical evidence for these tessellations. Along the same line of sight there are several sources of light and the redshifts are quantized. One speaks of God's fingers [**?**] [K23]. This is what any tessellation of cosmic voids would predict: cosmic redshift would define effective distance. Of course also tessellations in smaller scales can be considered.

2. Also ordinary atomic lattices could involve this kind of tessellations with atomic nuclei at the centers of the unit cells as voids. The space between nucleus and atom would literally be empty, even 4-D space-time would be absent!

3. Also the TGD inspired model for genetic code [L49] involves a particular tessellation of H^3 realized at the magnetic body (MB) of a biological system and realizing genetic code. This leads to the conjecture that genetic code is universal and does not characterize only living matter. It would be induced to the space-time surface in the sense that part of tessellation would define a tessellation at the space-time surface. At the level of dark matter at MB, 1-D DNA could also have 2-D and even 3-D analogs, even in ordinary living matter!

6.2 Key questions

The basic question to be discussed in the following is what the general ideas about 2-D minimal surfaces can teach about minimal surfaces in M^8 and H, and more generally, about quantum TGD.

6.2.1 Uncertainty Principle and $M^8 - H$ duality

The interpretation of M^8 as analog of momentum space [L41, L42] meant a breakthrough in the understanding of $M^8 - H$ duality but created also a problem. How can one guarantee that $M^8 - H$ duality is consistent with Uncertainty Principle (UP)? The surfaces to which one can assign well defined momentum in M^8 should correspond to the analogs of plane waves in H and geometrically to periodic surfaces.

The fact that at the level of M^8 the surfaces are algebraic surfaces defined by polynomials with rational coefficients poses therefore a problem. Periodicity requires trigonometric functions. The

introduction of real anlytic functions with rational Taylor coeffients would force the introduction of infinite-D extensions of rationals and make this possible. This is however in conflict with the idea about the finiteness of cognition forming the basic principle of adelic physics [L17, L16].

6.2.2 Is the category of polymials enough?

Is it possible to have periodic minimal surfaces at the level of H or at the level of both M^8 and H without leaving the category polynomials?

1. Could the non-local character of the $M^8 - H$ duality in CP_2 degrees freedom miraculously give rise to periodic functions at the level of H? Or should one perhaps modify $M^8 - H$ duality itself to achieve this [L50].

2. Periodic frames assignable to light-like curves in M^8 as light-like curves would allow to achieve periodicity in the same manner as for helicoid but this requires the extension of the category of real polynomials to real analytic functions in M^8. One could even give up the assumption about a Taylor expansion with rational coefficients and assume that the coefficients belong to some possibly transcendental extension of rationals. This option would make sense in $\Lambda = 0$ phase.

3. Or could geometry come in rescue of algebra? Could one construct periodic surfaces both at the level of M^8 and H purely geometrically by gluing minimal surfaces together to form repeating patterns as is done for 2-D minimal surfaces? This option could work in $\Lambda > 0$ phases: smoothness at the junctions would be given up but local conservation laws would hold true for the entire action rather than for volume term and Kähler action separately.

If transcendental extensions are allowed, they would naturally contain some maximal root $e^{1/n}$ and its powers. The induced extension of p-adics is finite-D since e^p is an ordinary p-adic number. Logarithms of $log(k)$, $1 \leq k \leq p$, and their powers are needed to define p-adic logarithm for given p. The outcome is an infinite-D extension. Also π and its powers are expected to belong to the minimal transcendental extension.

It came as a surprise to me that is not known whether e and π are algebraically independent over rationals, that is whether a polynomial equation $P(x, y) = 0$ with rational coefficients is true for $(x, y) = (\pi, e)$ (`https://cutt.ly/xmyL23W`.) This would imply that π belongs to the extension defined by the polynomial $P(y, e)$ in an extension of rationals by e. Same would be true in the corresponding finite-D extensions of p-adic numbers. The algebraic independence of π and e would have rather dramatic implications for the TGD view about cognition. That π and e are algebraically independent follows from a more general conjecture by Schanuel and `https://cutt.ly/ImyL1YJ`).

6.2.3 Is also $\Lambda > 0$ phase physically acceptable?

Can one allow also $\Lambda = 0$ phase for the action. In this case the action reduces to mere Kähler action defined by M^4 and CP_2 Kähler forms analogous to self-dual covariantly constant $U(1)$ gauge fields? Could one see $\Lambda = 0$ phase as an analog of Higgs=0 phase?

In this phase the category of rational functions would expand to a category of real analytic functions and infinite extensions of rationals containing transcendental numbers would be unavoidable and allow light-like curves as frames instead of piecewise light-like geodesics.

One could argue that since the evolution of mathematical consciousness has led to the notion transcendentals and transcendental functions, they must be realized also at the level of space-time surfaces.

One can invent objections against the $\Lambda = 0$ phase for which Kähler action has only CP_2 part and serving at the same time as arguments for the necessity of M^4 part.

1. For a mere CP_2 Kähler action, the CP_2 type extremals representing building bricks of elementary particles become vacuum extremals and are lost from the spectrum. However, also the M^4 part of Kähler action predicted by the twistor lift gives rise to Chern-Simons (C-S) term assignable to the light-like 3-surface X^3_L as the orbit of partonic 2-surface and one can assign a momentum to X^3_L. The boundary conditions guaranteeing momentum conservation make possible momentum exchange between interior and X^3_L.

2. CP_2 Kähler action has a huge vacuum degeneracy since space-time surfaces with 2-D Lagrangian manifold as a CP_2 projection are vacuum extremals. $\Lambda > 0$ eliminates most of these extremals. Also the M^4 part of Kähler action, which vanishes for canonically imbedded M^4, implies that most vacuum extremals of CP_2 Kähler action cease to be extremals even for $\Lambda = 0$.

While writing the first version of this article I had not realized that what the correct form for the Kähler property in M^4 case is.

1. Suppose for definiteness the simplest option that the M^4 Kähler form are associated with the decomposition $M^4 = M^2 \times E^2$. A more general decomposition corresponds to Hamilton-Jacobi structure in which the distributions for $M^2(x)$ and $E^2(x)$ orthogonal to each other are integrable and define slicings of M^4 [L53].

2. The naive guess was that $J^2 = -g$ condition must be satisfied. This implies that the M^2 part of Kähler form of $M^4 = M^2 \times E^2$ decomposition has an electric part, which is imaginary so that the energy density is of form $-E^2 + B^2$ ($= 0$ for M^4). For instance, solutions of $M^2 \times Y^2$, where Y^2 is any Lagrangian manifold of CP_2 would have negative energy for $\Lambda = 0$. Even worse, Kähler gauge potential would be imaginary and the modified Dirac equation would be non-hermitian.

3. The problem disappears by noticing that the M^2 by its signature has hypercomplex rather than complex structure, which means that the counterpart of the imaginary unit satisfies $e^2 = 1$ rather than $i^2 = -1$. This allows a real Kähler electric field and the situation is the same as in Maxwell's theory.

6.3 About 2-D minimal surfaces

A brief summary about 2-D minimal surfaces and questions raised by them in TGD framework is in order. One can classify minimal surfaces to those without frame and with frame.

6.3.1 Some examples of 2-D minimal surfaces

The following examples about minimal surfaces are collected from the general Wikipedia article about minimal surface `https://cutt.ly/Hn673ry`) and various other Wikipedia articles. This article gives also references to articles (for instance the article "The classical theory of minimal surfaces" of Meeks and Perez [A7]) and textbooks discussing minimal surfaces , see for instance [A5]. Also links to online sources are given. "Touching Soap Films - An introduction to minimal surfaces" `https://cutt.ly/dmwMnJ7`) serves as a general introduction to minimal surfaces). There is also a gallery of periodic minimal surfaces (`https://cutt.ly/RmwMQ49`), which is of special interest from the TGD point of view.

1. Minimal surfaces without frame

In E^3 frameless minimal surfaces have an infinite size and are often glued from pieces, which asymptotically approach a flat plane.

Catenoid (`https://cutt.ly/in675Z6`) is obtained by a rotation of a catenoid, which is the form of the chain spanned between poles of equal height in the gravitational field of Earth. Catenoid has two planes as asymptotics and is obtained from torus by adding two punctures. Costa's minimal surface (`https://cutt.ly/in65wyP`) is obtained from torus by adding a single puncture and its second end looks like a catenoid.

Frameless minimal surfaces in E^3 allow also lattice-like structures. Schwarz minimal surface (`https://cutt.ly/dn65rJm`) is an example about minimal giving rise to 3-D lattice like structure. These surfaces have minimal genus $g = 3$.

In compact spaces closed minimal surfaces are possible and some quite surprising results hold true, see the popular article "*Math Duo Maps the Infinite Terrain of Minimal Surfaces*" (`http://tinyurl.com/yyetb7c7`). These surfaces have area proportional to volume of the embedding space and the explanation is that these surfaces fill the volume densely [A3, A4].

2. Minimal surfaces with lattice like structure

There exists also minimal surfaces with lattice-like structure.

1. Riemann described a one parameter of minimal surfaces with a 1-D lattice structure consisting of shelfs connected by catenoids (https://cutt.ly/Pn65y3f).

2. Scherk surfaces (https://cutt.ly/3n65oeB) are singly or doubly periodic. Scwartz surfaces (https://cutt.ly/un65pCK) are triply periodic structures defining 3-D lattices and have minimal genus $g = 3$. This kind of surfaces have been used to model condensed matter lattices. These surfaces have also hyperbolic counterparts.

3. Minimal surfaces spanned by frames

Minimal surfaces with frames allow to models soap films and are obtained as a solution of the Plateau's problem (https://cutt.ly/7n65fgT).

1. Helicoid (https://cutt.ly/Wn65jgT) represents a basic example of a simply periodic framed surface. Also helicoid involves transcendental functions. A portion of helicoid is locally isometric to catenoid.

2. Arbitrary curves can serve as frames with some mild restrictions. The minimal surface need not be unique. A given 2-D minimal surface is obtained in topological sense from a compact manifold by adding a puncture to represent boundaries defined by frames or the boundaries at infinity.

6.3.2 Some comments on 2-D minimal surfaces in relation to TGD

The study of the general properties of 2-D minimal surfaces from the TGD perspective suggest a generalization to the TGD framework and also makes possible a wider perspective about TGD itself.

1. Frameless minimal surfaces in TGD framework

Frameless minimal surfaces in E^3 have infinite sizes since they are locally saddle like. In TGD framework, the most interesting space-time surface are expected to be framed. Despite this frameless minimal surfaces are of interest.

1. In the TGD framework the minimal surfaces could extend to infinity in time-direction and remain finite in spatial directions. The asymptotically flat 2-plane could in TGD correspond to the simplest extremals of action: M^4 and "massless extremals" (MEs); surfaces $X^2 \times Y^2$ with X^2 a string world sheet and Y^2 complex manifold of CP_2; and CP_2 type extremals with 1-D light-like curve as CP_2 projection.

   Conservation laws do not allow M^4 even in principle unless the total angular momentum and color charges vanish. Various singularities could deform flat M^4 in close analogy with point and line charges.

2. In curved compact spaces also closed minimal surfaces are possible [A3, A4] (http://tinyurl.com/yyetb7c7). One can wonder whether CP_2 as a curved space might allow a volume-filling closed 2-D or 3-D minimal surfaces besides complex surfaces and minimal Lagrangian manifolds [L29]. For $\Lambda > 0$, only complex surfaces defined by polynomials in M^8 appear in PEs. It is difficult to see how this kind of exotic structure could define a physically interesting partonic 2-surface although formally one could consider a product of string world sheet and this kind of 2-surface.

2. Minimal surfaces with lattice structure

2-D minimal surfaces in E^3 allow lattice-like structures with dimensions 1, 2 and even 3. They are are interesting also in TGD framework.

1. Scwartz surface (https://cutt.ly/un65pCK), call it S, allows in the TGD framework a variant of form $M^1 \times S \times S^1$, where S^1 is a geodesic sphere. Same applies to all 2-D minimal

surfaces allowing a lattice structure and could be in a central role in condensed matter physics according to TGD. Also hyperbolic variants of a lattice like structure expected to relate to the tessellations of hyperbolic 3-space can be considered and could play important role at the level of magnetic bodies (MBs) as indeed suggested [L49].

2. If $\Lambda = 0$ phase is physically acceptable, it would make possible light-like curves as frames and also lattice-like minimal surfaces with periodicity forced by that of the light-like curve assignable to to CP_2 type extremal as M^8 pre-image.

   Note that $\Lambda = 0$ phase relates to $\Lambda > 0$ phase by the breaking of conformal symmetry transforming light-like curves to light-like geodesics. The interpretation of $\Lambda = 0$ phase in terms of the emergence of continuous string world sheet degrees of freedom is attractive.

   Another interpretation would be based on the hierarchy of Jones inclusions of hyper-finite factors of type II_1 (HFFs). $\Lambda > 0$ phase would define the reduced configuration space ("world of calassical worlds" (WCW)) in finite measurement resolution defined by the included HFF representing measurement resolution and $\Lambda = 0$ phase as the factor without this reduction. The approximation of real analytic functions by polynomials of a given degree would define the inclusion. This sequence of approximations would be realized as genuine physical systems ,rather than only approximate descriptions of them.

3. For $\Lambda > 0$ allowing only polynomial function, periodic smooth minimal surfaces in M^8. The construction of Schwartz surface suggests how one can circumvent this difficulty.

   Schwartz surface defines a 3-D lattice obtained by gluing together analogs of unit cells. If a region of a minimal surface intersects orthogonally a plane, the gluing of this surface together with its mirror image gives rise to a larger minimal surface and one can construct an entire lattice-like system in this way. These surfaces are not smooth at the junctions.

   In the TGD framework, one would construct lattice in time direction and the gluing would occur at edges defined by 3-D $t = r_n$ planes ("very special moments in the life of self" [L28]). Local conservation laws as limits of field equations are enough and derivatives can be discontinuous at $t = r_n$ planes. The expected non-uniqueness of the gluing procedure would mean a partial failure of the strict classical determinism having a crucial role in the understanding of cognition in ZEO. This is discussed in [L52].

   M^8-picture suggests a very concrete geometric recipe for constructing minimal surfaces periodic in time direction and this would make it possible to realize UP for $M^8 - H$ duality.

The general vision would be that $\Lambda > 0$ phases the periodic minimal surfaces can be constructed as piecewise smooth lattice-like structures in the category of real polynomials by using the gluing procedure whereas in $\Lambda = 0$ phase they correspond to smooth surfaces in the category of real analytic functions.

3. Minimal surfaces spanned by frames

Minimal surfaces spanned by frames are of special interest from TGD point of view.

1. In the TGD framework. Minimal surfaces are spanned by fixed frames at the boundary of CD and by dynamically generated frames in the interior of CD. The dynamically generated frames break strict determinism, which means that space-time surfaces as analogs of Bohr orbits becomes non-unique [L52] and holography (for its various forms see [L41, L42]) forced by the General Coordinate Invariance is not completely unique.

2. CP_2 type extremal in H would correspond to 1-D singularity in M^8 analogous to a frame assigned 2-D minimal surfaces. The physical picture suggests that this curve is a light-like curve for the Kähler action ($\Lambda = 0$) and a light-like geodesic for action involving also volume term ($\Lambda > 0$). In the first case the periodicity of the light-like curve could give rise to periodic minimal surfaces as generalization of helicoid. In the second case discretized variants could replace these curves.

3. For the minimal surfaces discussed above, polynomials are not enough for their construction and the examples involve transcendental functions like trigonometric, exponential and logarithmic functions in their definition.

The same is expected to be true also in TGD. Should one leave the category of polynomials and allow all real analytic functions with rational Taylor coefficients? Or should one assume also the $\Lambda = 0$ phase making possible real analytic functions?

As far as cognitive representations are involved, this would mean that cognition becomes infinite since the extensions of p-adic become infinite. Could $\Lambda = 0$ phase be associated with an expansion of consciousness, kind of enlightment, and relate to mathematical consciousness?

6.4 Periodic minimal surfaces with periodicity in time direction

There are several motivations for the periodic minimal surfaces.

6.4.1 Consistency of $M^8 - H$ duality with Uncertainty Principle

Consistency of $M^8 - H$ duality with UP is one motivation.

1. M^8 is interpreted as an analog of momentum space. $M^8 - H$ correspondence must be consistent with UP. If $M^8 - H$ correspondence in M^4 degrees of freedom involves inversion of form $m^k \to \hbar_{eff} m^k/m^2$. [L41, L42, L50]. This solves the problem only partially. $M^8 - H$ correspondence should realize also the idea about plane wave as space-time counterpart of point in momentum space.

   The first guess [L50] would be that the $X^4 \subset CD \subset M^8$ is mapped to a union of translates of images of CD by inverse of P^k, where is the total momentum assignable to CD. What I saw as a problem, was that this gives a lattice-like many-particle state rather than a single particle state as a counterpart of a plane wave.

   If the momentum is space-like, this is indeed the case. Therefore I proposed that the image is a quantum superposition of translates rather than their union and represents an analog of plane wave. I failed to realize that this is not the case for time-like momentum since periodicity in time direction does not mean lattice as many-particle state.

   A geometric correspondence for time-like momenta is possible after all! The problem is a concrete realization of this correspondence and here the geometric construction gluing together the analogs of unit cells to form a periodic structure in time direction suggests itself.

2. Quite concretely, one could take part of $X^4 \subset CD \subset M^8$ defining particle and construct a periodic surface with a period determined by the total time-like momentum assignable to this part of X^4. X^4 has a slicing by planes $e = e_n$ [L28] assignable to 6-branes with topology of S^6 defining universal special solutions of algebraic equations. Here e_n is a root of the real polynomial defining X^4.

   One could take a piece $[e_1, ..., e_k]$ of $X^4 \subset CD$ and glue it to its time reversal in M^8 to get a basic unit cell and fuse these unit cells together to obtain a periodic structure.

   The differences $e_i - e_j$, which for M^8 correspond to energy differences, are mapped by inversion to time differences $t_i - t_j$ in H. The order of magnitude for the p-adic length scale assignable to CD in question is the same as for the largest difference for the roots as conjectured on basis of the conjecture that the p-adic length scale correspond to a ramified prime of the extension dividing $|t_i - t_j|^2$ for some pair (i, j). The p-adic prime for CD need not however be a ramified prime and one can develop an argument for how it emerges [L52].

3. Rather remarkably, one can glue together portions $[t_1, ..t_r]$ and the mirror image of $[t_k, t_r]$, for any k. All possible sequences of this kind are possible! This suggests an analogy to logical reasoning: $[t_n, t_{n+1}]$ would represent a basic step $t_n \to t_{n+1}$ in the reasoning and one could combine these steps. Could this process serve as the geometric correlate for logical thought or as engineeering at the level of fundamenta interactions?

   The physicalists refusing to accept non-determinism at the fundamental level fail to realize that our technology relies on a fusion of deterministic processes and is therefore not consistent with strict determinism. Also computer programs consist of deterministic pieces.

4. There is still one open question. Does the construction of the time lattices occur only at the level of H or both at the level of M^8 and H? One can argue that the realization of the analog of inverse Fourier transform forces the construction at both sides.

6.4.2 Bohr orbitology for particles in terms of minimal surfaces

In TGD, space-time surfaces correspond to analogs of Bohr orbits. One should also have classical space-time analogs for ordinary bound states as Bohr orbits for particles. Atoms represent the basic example. In TGD Universe, Bohr model should be much more than mere semiclassical model. Also the geodesic orbits of particles in gravitational fields should have minimal surface analogs.

The Bohr orbits should be representable as parts of minimal surfaces identifiable as deformed CP_2 type extremals. There are two options to consider corresponding to $\Lambda = 0$ phase and to $\Lambda > 0$ phases.

1. $\Lambda = 0$ *phase*

$\Lambda = 0$ phase corresponds to a long length scale limit but general consideratons encourage its inclusion as a genuine phase. Its relation to $\Lambda > 0$ phases would be like the relation of real numbers to extensions of rationals and transcendental functions to polynomials.

1. For $\Lambda = 0$, CP_2 type extremals are vacuum extremals and correspond to 1-D singularities, which are light-like curves in M^8 blown up to orbits of wormhole contacts in H.

   Light-like curve as an M^4 projection of Bohr orbit of this kind can give rise to "zitterbewegung" as a helical motion with average cm velocity $v < c$. The proposal for the TGD based geometric description of Higgs mechanism realizes this zitterbewegung of CP_2 type extremals for Kähler action. This makes it possible to assign to any particle orbit - be it Bohr orbit in an atom or a geodesic path in a gravitational field, an average of a light-like curve.

2. Light-likeness gives rise to Virasoro conditions emerging in the bosonic string theories. This served as a stimulus leading to the assignment of extended Kac-Moody symmetries to the light-like partonic orbits X^3 . The isometries of H define the extended Kac-Moody group. The generators of the Kac-Moody algebra depend on the complex coordinate z of the partonic 2-surface and on the light-like radial coordinate of X^3. Super-symplectic symmetries assigned to the light-like $\delta M^4_{\pm} \times CP_2$ and identified as isometries of WCW have an analogous structure [K21] [L44].

   The light-like orbits of the partonic 2-surfaces in H are connected by string world sheets. The interpretation could be that in $\Lambda = 0$ phase strings emerge as additional degrees of freedom.

3. For CP_2 part of Kähler action $\Lambda = 0$ CP_2 type extremals are vacua (this need not be the case for the deformations). The C-S term for CP_2 Kähler action carries no momentum and cannot contribute to momentum and cannot realize momentum conservation for deformed CP_2 type extremals.

   However, the C-S term for the M^4 part of Kähler action defines the partonic orbits as dynamical entities. If the projection of the deformation of CP_2 type extremal at the wormhole throat has M^4 projection with dimension $D = 3$, M^4 C-S term gives rise to non-vanishing momentum currents and the smooth light-orbit is consistent with the momentum conservation if boundary conditions are realized. What is remarkable that M^4 C-S term also gives rise to small CP breaking, whose origin is not understood in the standard model. The tiny C-S breaking term would be paramount for the existence of elementary particles!

The implications of this picture are rather profound. It could be possible to assign to any physical system rather detailed view about the minimal surfaces involved both at the level of H and M^8.

Could tachyonic states appear as parts of non-tachyonic states somewhat like tachyonic virtual particles appear in Feynman graphs?

1. The possibly existing periodic minimal surfaces with tachyonic total momenta would have an interpretation as lattice-like many-particle states. This excludes them as unphysical. In fact, one cannot construct tachyonic periodic minimal surfaces in the proposed way since the planes $t = t_n$ have time-like normal.

2. M^8 picture allows to interpret tachyonicity as a trick. In the M^8 picture the choice of $M^4 \subset M^8$ is in principle free. The mass squared of the particle depends on this choice since M^4 momentum is a projection of M^8 momentum to $M^4 \subset M^8$. For eigenstates of M^4 mass, one can rotate $M^4 \subset M^8$ in such a way that the mass squared vanishes. For a superposition of states with different mass squared possible in ZEO this is not possible but one can choose M^4 so that mass squared is minimized. This gives rise to p-adic thermodynamics as a description for the mixing with heavier states.

   One could understand the tachyonic ground state as an effective description for the choice of M^4 in this manner.

2. $\Lambda > 0$ phase

For $\Lambda > 0$ only light-like geodesics are possible and this forces a modification of the above picture by replacing light-like curves with piece-wise light-like geodesics.

1. A discrete variant of zitterbewegung consisting of pieces of light-like geodesics is suggestive. The dynamics in stringy degrees of freedom would be almost frozen and completely dictated by the ends of the string. Discretized version of smooth dynamics would be in question. This kind of phenomenological model for hadronic strings has been proposed.

2. The change of the direction of the partonic orbit takes place in a vertex. In M^8 picture it is associated with a partonic 2-surface associated with a $t = r_n$ hyperplane at which several CP_2 type extremals meet at the level of H. These reactions could be seen as ordinary particle reactions.

3. Another way to change the direction would be based on the interaction of parton with the interior degrees of freedom so that conservation laws are not lost. The interaction between the 3-D orbit of wormhole throat and interior is defined by the condition that normal components of the isometry currents of the total Kähler action are equal to the divergences of C-S currents the partonic orbit. For the M^4 part of C-S action only momentum currents are non-vanishing whereas for CP_2 only color currents are non-vanishing.

   At the turning points the normal current of the entire Kähler action - and the divergence of the isometry current for C-S part CP_2 type extremal must become non-vanishing and divergent but cancel each other. Local conservation laws hold true and one can speak of a momentum exchange between interior and wormhole throat. This picture applies also to color currents.

3. A connection with Higgs mechanism

The fact that zitterbewegung makes the particle effectively massive in long enough scales, suggests an analogy with the massivation by the Higgs mechanism.

1. The interactions between partonic orbits and the interior of the space-time surface are analogous to the interactions of particles with a Higgs field leading to the massivation as the Higgs field develops a vacuum expectation value.

2. M^4 Kähler form represents a constant self-dual Abelian gauge field. Although this field is not a scalar field, it is analogous to the vacuum expectation value of the Higgs field as far as its effects are considered.

4. A connection twistor diagrams and generalization of cognitive representations

Also a connection with twistor diagrams is suggestive. The light-like geodesic lines appearing as 1-D singularities in M^8 would correspond to light-like differences of the time-like momenta assignable to vertices. In H they are assignable with partonic 2-surfaces identifiable as boundaries of 3-D blow ups of 1-D singularities in M^8. In M^8, the graphs containing time-like momenta connected by singular lines would define analogs of twistor diagrams. Also at the level of H the lines connecting partonic 2-surfaces would be light-like as also the distances between them since the inversion map preserves light-likeness of the tangent curves.

This would pose additional conditions on cognitive representations.

1. The original proposal [**?**]as that cognitive representation consists of points of X^4 for which M^8 coordinates belong to the EQ associated with the polynomial considered. The expectation was that one has a generic situation so that this set is automatically finite.

   The explicit solution of the polynomial equations however led to a surprising finding was that the number of these points was a dense set for the space-time surfaces satisfying co-associativity conditions [L41, L42]. The second surprise was that co-associativity (associativity of normal space) is the only possible option.

2. The additional conditions guaranteeing that the cognitive representation consists of a finite number of objects, generalize it from a discrete set of points to a union of singularities with co-dimension $d_c = 4 - d$, $d = 1, 2, 3$.

   The vertices would be connected by $d = 1$ light-like singularities and belong to 2-D partonic 2-surfaces as $d = 2$ singularities at $t = r_n$ surfaces in turn defining $d = 3$ singularities. Also 2-D string world sheets having $d = 1$ singularities as boundaries would be included.

3. This would also generalize twistor diagrams as a frame holographically coding for the space-time surface as an analog of Bohr orbit. At the M^8 level, the definition of the parts of this structure would involve only parameters with values in EQ (say the end points of a light-like geodesic defining it).

6.4.3 Periodic self-organization patterns, minimal surfaces, and time crystals

Periodic self-organization patterns which die and are reborn appear in biology. Even after images, which die and reincarnate, form this kind of periodic pattern. Presumably these patterns would relate to the magnetic body (MB), which carries dark matter in the TGD sense and controls the biological body (BB) consisting of ordinary matter. The periodic patterns of MB represented as minimal surface would induce corresponding biological patterns.

The notion of time crystal [B2] (`https://cutt.ly/2n65x0k`) as a temporal analog of ordinary crystals in the sense that there is temporal periodicity, was proposed by Frank Wilczeck in 2012. Experimental realization was demonstrated in 2016-2017 [D3] but not in the way theorized by Wilczek. Soon also a no-go theorem against the original form of the time crystal emerged [B4] and motivated generalizations of the Wilzeck's proposal.

Temporal lattice-like structures defined by minimal surfaces would be obvious candidates for the space-time correlates of time crystals.

1. One must first specify what one means with time crystals. If the time crystal is a system in thermo-dynamic equilibrium, the basic thermodynamics denies periodic thermal equilibrium. A thermodynamical non-equilibrium state must be in question and for the experimentally realized time crystals periodic energy feed is necessary.

   Electrons constrained on a ring in an external magnetic field with fractional flux posed to an energy feed form a time crystal in the sense that due to the repulsive Coulomb interaction electrons form a crystal-like structure which rotates. This example serves as an illustration of what time crystal is.

2. Breaking of a discrete time translation symmetry of the energy feed takes place and the period of the time crystal is a multiple of the period of the energy feed. The periodic energy feed guarantees that the system never reaches thermal equilibrium. According to the Wikipedia article, there is no energy associated with the oscillation of the system. In rotating coordinates the state becomes time-independent as is clear from the example. What comes to mind is a dynamical generation of Galilean invariance applied to an angle variable instead of linear spatial coordinate.

3. Also the existence of isolated time crystals has been proposed assuming unusual long range interactions but have not been realized in laboratory.

Time crystals are highly interesting from the TGD perspective.

1. The periodic minimal surfaces constructed by gluing together unit cells would be time crystals in geometric sense (no thermodynamics) and would provide geometric correlates for plane waves as momentum eigenstates and for periodic self-organization patterns induced by the periodic minimal surfaces realized at the level of the magnetic body. It is difficult to avoid the idea that geometric analogs of time crystals are in question.

2. The hierarchy of effective Planck constants $h_{eff} = nh_0$ is realized at the level of MB. To preserve the values of h_{eff} energy feed is needed since h_{eff} tends to be reduced spontaneously. Therefore energy feed would be necessary for this kind of time crystals. In living systems, the energy feed has an interpretation as a metabolic energy feed.

   The breaking of the discrete time translation symmetry could mean that the period at MB becomes a multiple of the period of the energy feed. The periodic minimal surfaces related to ordinary matter and dark matter interact and this requires con-measurability of the periods to achieve resonance.

3. Zero energy ontology (ZEO) predicts that ordinary ("big") state function reduction (BSFR) involves time reversal [L35, L52]. The experiments of Minev *et al* [L25] [L25] give impressive experimental support for the notion in atomic scales, and that SFR looks completely classical deterministic smooth time evolution for the observer with opposite arrow of time. Macroscopic quantum jump can occur in all scales but ZEO together with h_{eff} hierarchy takes care that the world looks classical! The endless debate about the scale in which quantum world becomes classical would be solely due to complete misunderstanding of the notion of time.

4. Time reversed dissipation looks like self-organization from the point of view of the external observer. A sub-system with non-standard arrow of time apparently extracts energy from the environment [L31]. Could this mechanism make possible systems in which periodic oscillations take place almost without external energy feed?

Could periodic minimal surfaces provide a model for this kind of system?

1. Suppose that one has a basic unit consisting of the piece $[t_1, .., t_k]$ and its time reversal glued together. One can form a sequence of these units.

   Could the members of these pairs be in states, which are time reversals of each other? The first unit would be in a self-organizing phase and the second unit in a dissipative phase. During the self-organizing period the system would extract part of the dissipated energy from the environment. This kind of state would be "breathing" [L62].

   There is certainly a loss of energy from the system so that a metabolic energy feed is required but it could be small. Could living systems be systems of this kind?

2. One can consider also more general non-periodic minimal surfaces constructed from basic building bricks fitting together like legos or pieces of a puzzle. These minimal surfaces could serve as models for thinking and language and behaviors consisting of fixed temporal patterns.

7 Double slit experiment in time domain from the TGD perspective

The temporal analog of the double slit experiment carried out by a research team led by Riccardo Sapienza [D2] has gained a lot of attention. The experiment is a generalization of the regular double slit experiment to the time domain (`rebrand.ly/tmbz3gu`).

I am grateful to Tuomas Sorakivi for turning my attention to a Youtube video "Light Can Interfere in Time as well as Space" by Ben Milles (`rebrand.ly/zz3jq2a`). The discussions in our Zoom group about the experiment inspired this article and led to an idea that the testing of the basic predictions of zero energy ontology might be possible.

There are also popular articles about the experiment in Live Science (`rebrand.ly/o0ojyya`) and in Quantum Insider (`rebrand.ly/y3k24gl`).

The following is the abstract of the research article [D2]:

"Double-slit experiments—where a wave is transmitted through a thin double aperture in space—have confirmed the wave–particle duality of quantum objects, such as single photons, electrons, neutrons, atoms and large molecules. Yet, the temporal counterpart of Young's double-slit experiment—a wave interacting with a double temporal modulation of an interface—remains elusive. Here we report such a time-domain version of the classic Young's double-slit experiment: a beam of light twice gated in time produces an interference in the frequency spectrum.

The 'time slits', narrow enough to produce diffraction at optical frequencies, are generated from the optical excitation of a thin film of indium tin oxide near its epsilon-near-zero point. The separation between time slits determines the period of oscillations in the frequency spectrum, whereas the decay of fringe visibility in frequency reveals the shape of the time slits.

Surprisingly, many more oscillations are visible than expected from existing theory, implying a rise time that approaches an optical cycle. This result enables the further exploration of time-varying physics, towards the spectral synthesis of waves and applications such as signal processing and neuromorphic computation."

The temporal analog of double slit experiments are expected to have many technological applications:

"The observation of temporal Young's double-slit diffraction paves the way for the optical realizations of time-varying metamaterials, promising enhanced wave functionalities such as non-reciprocity, new forms of gain, time reversal and optical Floquet topology. The visibility of oscillations can be used to measure the phase coherence of the wave interacting with it, similar to wave–matter interferometers. Double-slit time diffraction could be extended to other wave domains, for example, matter waves, optomechanics and acoustics, electronics and spintronics, with applications for pulse shaping, signal processing and neuromorphic computation."

Double slit experiment in spatial domain

One can look at the description of the situation in Maxwell's classical theory first. One has two slits at the first screen characterized by their distance and their widths. They parameterize the diffraction pattern at the second screen. The beam can be assumed to be monochromatic and normal to the screen.

Formally one can say that the transparency of the screen containing the slits is varying. It vanishes outside the slits and is maximal at the slits. The transparency of the screen depends on position. The modelling based on Maxwell's equations assumes incoming beam of light, say plane wave in definite direction and presence of the first screen described in terms of transparency. One can solve Maxwell's equations and predict the diffraction pattern.

One can study the spatial interference pattern at the second screen or equivalently, its Fourier transform with respect to a coordinate parallel to the screen and in the direction vertical to the parallel slits. One obtains a diffraction pattern also in the space of wave vectors (photon momenta in the quantum situation). The dominating peak is associated with the wave vector associated with the incoming beam.

In the diffraction, the normal component of the wave vector is conserved but the tangential component can change. This gives rise to dispersion with respect to the tangential component of the wave vector. At single photon level one can say that the slit scatters the incoming photons to various directions.

Hitherto everything has been purely classical. What makes the phenomenon so remarkable is that the double slit diffraction patterns appear also when single photons are used. This takes place also for other particles. The classical view of a particle would predict two peaks behind the slits.

7.1 Double slit experiment in time domain

What happens in the temporal double slit experiment is very similar to what happens in the regular case. One cannot directly measure the temporal patterns of the reflected wave. One can however measure the intensity as a function of frequency characterized by the Fourier transform of the reflected electromagnetic field. If one is also able to determine the phases of the Fourier components theoretically, one could also estimate the fields at the level of space-time, even those before the first pump pulse.

The frequency distribution is qualitatively similar to that for the wave vector distribution in the regular double slit experiment. Slit becomes pulse, slit width becomes the duration of pulse,

and the distance between slits becomes the interval between pulses.

The effect is stronger than expected for short pulse durations approaching the optical cycle $T = 1/f$ where f is the frequency of the incoming laser beams. The proposal is that what matters is the time scale τ for the change from transparency to reflectivity lasting as the duration of the pulse. One has $\tau = 2.3$ fs is roughly one half of the period $T = 1/f = 4.4$ fs of the period of incoming laser beam. The duration between pulses is .8 ps.

During period τ the dispersion of the chromatic beam to frequencies around the peak frequency would take place and could be understood mathematically as following from the time dependence of the refractive index (or reflection coefficient).

The frequency dispersion occurs already for a single pulse and gives rise to a single maximum as in the case of the ordinary single slit experiment. For two pulses a diffraction pattern in the frequency domain resembling that of the double slit experiment is observed. The shorter the duration of the pulse is and the shorter the time interval between slits is, the more pronounced the diffraction pattern is.

Maxwell's equations in the presence of the screen with time dependent refractive index describes the situation classically in the first approximation. Time dependent refractive index characterizes the screen. Refractive index does not change during the period between pump pulses but changes during the period τ to a constant value preserved during the pump pulse and after that returns to its original value. The interpretation would be that pump pulse feeds to the system energy needed to keep the value of the refractive index constant allowing reflection. One can say that during the pulse the system is not closed.

In the Maxwellian view, the reflected fields propagate with a light velocity. This gives rise to classical causality. The temporal field pattern of the reflected wave deducible by the inverse Fourier transform from its frequency pattern should vanish before the first pulse. But is this really the case? Time reversal is mentioned in the abstract of the article: is there evidence that this is actually not the case?

7.2 TGD view of the double-slit experiment in temporal domain

Consider next the TGD [L53] based quantum view of the situation.

7.2.1 Basic incredients

There are several new ingredients involved.

1. TGD leads to a new view of space-time [L61]. Point-like particles are replaced by 3-surfaces in $H = M^4 \times CP_2$ and their orbits determine space-time regions. The regions of space-time surface obey almost deterministic holography, being analogous to Bohr orbits.

2. Holography forces zero energy ontology (ZEO) [L35, L22, L55, L52] replacing the standard ontology of quantum theory and solving the basic paradox of the quantum measurement theory. ZEO also leads to a new view of what occurs in state function reductions (SFRs).

3. Number theoretic view of TGD predicts a hierarchy of effective Planck constants $h_{eff} = nh_0$ [K6, K7, K8, K9] characterizing phases of ordinary matter behaving in many respects like dark matter. They allow long length scale quantum coherence. In the recent case, laser beams could have $h_{eff} > h$.

4. Momentum position duality is generalized to $M^8 - H$ duality [L41, L42, L59], which states that the M^8 picture providing algebraic and number theoretic view of physics is complementary to the geometric view of physics.

This framework could allow totally new insights of the double slit experiment in the time domain.

7.2.2 ZEO briefly

I have explained ZEO so many times that I will give only a very brief sketch.

1. In ZEO, quantum states are superpositions of classical time evolutions obeying almost, but not quite(!) exact holography [L60, L61, L57]. These time evolutions correspond to space-time surfaces analogous to Bohr orbits. These space-time surfaces are within a causal diamond (CD) and zero energy states are pairs of 3-D states as analogs of ordinary 3-D quantum states at the opposite boundaries of the CD identifiable as superpositions of 3-surfaces.

2. There are two kinds of state function reductions (SFRs) [K26] [L35, L52, L22]. "Small" SFRs (SSFRs) preserve the arrow of time, and their sequence is the counterpart for repeated quantum measurements which do not affect the system at all (Zeno effect). SSFRs do not affect the passive boundary nor 3-D states at it. SSFRs affect the states at the active boundary of CD and in a statistical sense shift it farther away from the passive boundary. This shifting corresponds to the increase of the geometric time identified as the distance between the tips of CD. Geometric time therefore correlates with the subjective time identified as the sequence of SSFRs.

3. In "big" SFRs (BSFRs), which are counterparts of ordinary SFRs the arrow of time changes and the roles of active and passive boundaries of CD are changed. SSFRs correspond to a sequence of measurements of fixed observables. The states at the passive boundary are eigenstates for a subset of these observables and are not affected in SSFRs. When the set of measured observables changes by external perturbation, BSFR must occur and change the arrow of time temporarily. Quantum tunnelling would correspond to a temporary change of the arrow of time caused by two BSFRs.

Could ZEO make it possible to say something interesting about the time slit experiments?

1. In Maxwellian view the reflected fields propagate with light velocity. This gives rise to classical causality. In the Maxwellian picture, the temporal field pattern of the reflected wave, possibly deducible by inverse Fourier transform from its Fourier transform, should vanish before the first pulse. Is this really the case? Can this be tested? Time reversal is mentioned in the abstract of the article, is there evidence for the occurrence of a temporary time reversal.

2. Could the pump pulse induce BSFR and a temporary time reversal? The end of the pulse would induce a second BSFR and bring back the original arrow of time. Since SFRs replace the superposition of classical space-time surfaces (classical time evolutions and therefore field patterns) with a new one, the pair of BSFRs would change the classical field patterns also in the geometric past.

   Could the classical field patterns be deduced from the frequency spectrum of reflected waves? If it is possible to estimate the phases of the Fourier components theoretically, it is in principle to estimate the classical spatiotemporal field patterns in the geometric past.

   If they violate classical causality, i.e. are non-vanishing before the first pump pulse, one can conclude that the experiment provides a strong support for ZEO. Quite generally, one might someday be able to measure what happens to the geometric past in BSFR pairs.

7.2.3 Can one determine the classical fields in the geometric by measuring the Fourier transform?

In principle, there are good hopes that in the TGD Universe it might be possible to deduce from the frequency spectrum of the reflected light the spatiotemporal behavior of the reflected wave in the geometric past and therefore test ZEO. There are several reasons for why this should be the case.

1. Classical fields are geometrized in TGD. For a single space-time surface the classical fields are determined completely by the surface itself as induced fields. This simplifies dramatically the mathematical picture.

2. Topological quantization means that Maxwellian classical fields decompose to topological field quanta, which or at least their M^4 projections have a finite size. One obtains a variety of field quanta. Massless extremals (MEs) are highly analogous to laser beams and represent precisely targeted propagation in which the pulses consisting of Fourier components with only a single direction of wave vector in the direction of ME preserve their shape.

   The pulse beam, incoming laser beam and reflected light beam(s) could be modelled in terms of MEs. The reflected beam could correspond to a ME representing a superposition of analogs of parallel plane waves with different frequencies. Monochromatic ME becomes multichromatic ME in the reflection. One could say that the frequency dispersion represents new physics predicted by TGD.

3. Holography makes it possible to deduce a given space-time surface from a 3-D holographic data, basically a set of 3-surfaces. There is no need to know the 4-D tangent spaces at the 3-surfaces.

   There is however a small violation of determinism for the holography, which in fact forces ZEO. At the space-time level this corresponds to the fact that space-time surfaces as minimal surfaces are not completely fixed by holographic data, which is analogous to frames spanning soap films.

4. Complexified M^8 is an analog of 8-D momentum space and a given 4-surface in M^8 is determined by roots of a polynomials, which correspond to mass shells $H^3 \subset M^4 \subset M^8 = M^4 \times E^4$. The 4-surface $Y^4 \subset M^8$ must go through 3-surfaces at these mass shells defining the holographic data.

   The condition that the normal space of 4-surface $Y^4 \subset M^8$ going through these mass shells is associative allows us to realize M^8 holography almost uniquely.

5. One can also apply M^8-H duality, which is analogous to momentum position duality of wave mechanics. $M^8 - H$ duality maps $Y^4 \subset M^8$ to a space-time surface $X^4 \subset H = M^4 \times CP_2$ and induces holography at the level of H. For space-time surfaces, holography means a generalization of holomorphy from 2-D to a 4-D situation.

   In particular, mass shells are mapped by the inversion mapping M^4 momentum value at mass shell to a light-cone proper time $a = constant$ hyperboloid in $M^4 \subset H$. The momentum components are in general algebraic integers and therefore complex. Therefore one must take the real part of the image by inversion. One has $p^k \to Re[h_{eff}p^k/p_lp^l]$ [L59].

   This works when mass squared $p^lkp_l = m^2$ is nonvanishing. Photons are however massless. In this case the inversion is ill-defined. In the massless case polynomials determine energy shells in M^4. In this case, the associative holography is based on energy shells. The inversion must map light-cones boundaries to light-cone boundaries. Complex algebraic integer valued energy E is mapped to $t = Re[h_{eff}/E]$.

6. 3-D holographic data at the mass shells in H^3, and in the special case at light-cone boundaries for massless photons, codes for the frequency spectrum and this in principle determines the classical fields in X^4 by $M^8 - H$ duality.

   Associative holography and $M^8 - H$ duality would make it possible to calculate the classical fields in the geometric past before the first pump pulse and test ZEO by comparing them with those predicted by the classical causality.

7. Number theoretical view brings in also the notion of finite measurement resolution, necessary for number theoretical universality needed when p-adic physics is introduced as a correlate for cognition. This simplifies further the situation.

   Finite measurement resolution requires a number theoretical discretization of mass shells, which is unique. Allowed 4-momenta components, which are algebraic integers for an algebraic extension determined by the polynomial P whose roots define mass shells in turn determining Y^4. The momentum unit corresponds to the size scale of the causal diamond (CD).

The physical states expressible as bound states of fundamental fermions and antifermions are Galois singlets for which momentum components are ordinary integers.

An interesting possibility is that, in a finite measurement resolution determined by the polynomial P, all space-time surfaces in the superposition defining a given zero energy state have the same number theoretic discretization. Finite measurement resolution would make the quantum states effectively classical apart from the non-determinism associated with the holography!

In principle, this picture would allow us to determine the classical fields in the geometric past from the frequency spectrum and to check whether they are consistent with the classical causality. The appearance of the reflected wave is already before the first pulse could be regarded as an empirical support, if not a proof for the ZEO!

Of course, in reality the space-time of standard model is determined as an approximation by replacing the space-time visualizable as topologically extremely complex many-sheeted structure with its M^4 projection such that the sums of the induced fields at various sheets define standard model gauge fields and gravitational field as the sum of the deviations of the induce metric from the Minkowski metric.

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