Negentropy Maximization Principle

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Contents

Abstract

In TGD Universe the moments of consciousness are associated with quantum jumps between quantum histories. The proposal is that the dynamics of consciousness is governed by Negentropy Maximization Principle (NMP), which states the information content of conscious experience is maximal. The formulation of NMP is the basic topic of this chapter.

NMP codes for the dynamics of standard state function reduction and states that the state function reduction process following U-process gives rise to a maximal reduction of entanglement entropy at each step. In the generic case this implies at each step a decomposition of the system to unique unentangled subsystems and the process repeats itself for these subsystems. The process stops when the resulting subsystem cannot be decomposed to a pair of free systems since energy conservation makes the reduction of entanglement kinematically impossible in the case of bound states. The natural assumption is that self loses consciousness when it entangles via bound state entanglement.

There is an important exception to this vision based on ordinary Shannon entropy. There exists an infinite hierarchy of number theoretical entropies making sense for rational or even algebraic entanglement probabilities. In this case the entanglement negentropy can be negative so that NMP favors the generation of negentropic entanglement (NE), which is not bound state entanglement in standard sense since the condition that state function reduction leads to an eigenstate of density matrix requires the final state density matrix to be a projection operator.

NE might serve as a correlate for emotions like love and experience of understanding. The reduction of ordinary entanglement entropy to random final state implies second law at the level of ensemble. For the generation of NE the outcome of the reduction is not random: the prediction is that second law is not a universal truth holding true in all scales. Since number theoretic entropies are natural in the intersection of real and p-adic worlds, this suggests that life resides in this intersection. The existence effectively bound states with no binding energy might have important implications for the understanding the stability of basic bio-polymers and the key aspects of metabolism. A natural assumption is that self experiences expansion of consciousness as it entangles in this manner. Quite generally, an infinite self hierarchy with the entire Universe at the top is predicted.

There are two options to consider. Strong form of NMP, which would demand maximal negentropy gain: this would not allow morally responsible free will if ethics is defined in terms of evolution as increase of NE resources. Weak form of NMP would allow self to choose also lower-dimensional sub-space of the projector defining the final state sub-space for strong form of NMP. Weak form turns out to have several highly desirable consequences: it favours dimensions of final state space coming as powers of prime, and in particular dimensions which are primes near powers of prime: as a special case, p-adic length scale hypothesis follows. Weak form of NMP allows also quantum computations, which halt unlike strong form of NMP.

Besides number theoretic negentropies there are also other new elements as compared to the earlier formulation of NMP.

1. ZEO modifies dramatically the formulation of NMP since U-matrix acts between zero energy states and can be regarded as a collection of orthonormal M-matrices, which generalize the ordinary S-matrix and define what might be called a complex square root of density matrix so that kind of a square root of thermodynamics at single particle level justifying also p-adic mass calculations based on p-adic thermodynamics is in question.
2. The hierarchy of Planck constants labelling a hierarchy of quantum criticalities is a further new element having important implications for conciousness and biology.
3. Hyper-finite factors of type II_1 represent an additional technical complication requiring separate treatment of NMP taking into account finite measurement resolution realized in terms of inclusions of these factors.

NMP has wide range of important implications.

1. In particular, one must give up the standard view about second law and replace it with NMP taking into account the hierarchy of CDs assigned with ZEO and dark matter hierarchy labelled by the values of Planck constants, as well as the effects due to NE. The breaking of second law in standard sense is expected to take place and be crucial for the understanding of evolution.
2. Self hierarchy having the hierarchy of CDs as imbedding space correlate leads naturally to a description of the contents of consciousness analogous to thermodynamics except that the entropy is replaced with negentropy.

3. In the case of living matter NMP allows to understand the origin of metabolism. NMP demands that self generates somehow negentropy: otherwise a state function reduction to tjhe opposite boundary of CD takes place and means death and re-incarnation of self. Metabolism as gathering of nutrients, which by definition carry NE is the manner to avoid this fate. This leads to a vision about the role of NE in the generation of sensory qualia and a connection with metabolism. Metabolites would carry NE and each metabolite would correspond to a particular qualia (not only energy but also other quantum numbers would correspond to metabolites). That primary qualia would be associated with nutrient flow is not actually surprising!
4. NE leads to a vision about cognition. Negentropically entangled state consisting of a superposition of pairs can be interpreted as a conscious abstraction or rule: negentropically entangled Schrödinger cat knows that it is better to keep the bottle closed.
5. NMP implies continual generation of NE. One might refer to this ever expanding universal library as "Akaschic records". NE could be experienced directly during the repeated state function reductions to the passive boundary of CD - that is during the life cycle of sub-self defining the mental image. Another, less feasible option is that interaction free measurement is required to assign to NE conscious experience. As mentioned, qualia characterizing the metabolite carrying the NE could characterize this conscious experience.
6. A connection with fuzzy qubits and quantum groups with NE is highly suggestive. The implications are highly non-trivial also for quantum computation allowed by weak form of NMP since NE is by definition stable and lasts the lifetime of self in question.

1 Introduction

Quantum TGD involves "holy trinity" of time developments. There is the geometric time development dictated by the preferred extremal of Kähler action crucial for the realization of General Coordinate Invariance and analogous to Bohr orbit. There is what I originally called unitary "time development" U: $\Psi_i \to U\Psi_i \to \Psi_f$, associated with each quantum jump. This would be the counterpart of the Schrödinger time evolution $U(-t, t \to \infty)$. Quantum jump sequence itself defines what might be called subjective time development.

Concerning U, there is certainly no actual Schrödinger equation involved: situation is in practice same also in quantum field theories. It is now clear that in Zero Energy Ontology (ZEO) U can be actually identified as a sequence of basic steps such that single step involves a unitary evolution inducing delocalization in the moduli space of causal diamonds CDs) followed by a localization in this moduli space selecting from a superposition of CDs single CD. This sequence replaces a sequence of repeated state function reductions leaving state invariant in ordinary QM. Now it leaves in variant second boundary of CD (to be called passive boundary) and also the parts of zero energy states at this boundary. There is now a very attractive vision about the construction of transition amplitudes for a given CD [K25], and it remains to be see whether it allows an extension so that also transitions involving change of the CD moduli characterizing the non-fixed boundary of CD.

A dynamical principle governing subjective time evolution should exist and explain state function reduction with the characteristic one-one correlation between macroscopic measurement variables and quantum degrees of freedom and state preparation process. Negentropy Maximization Principle is the candidate for this principle. In its recent form it brings in only a single little but overall important modification: state function reductions occurs also now to an eigen-space of projector but the projector can now have dimension which is larger than one. Self has free will to choose beides the maximal possible dimension for this sub-space also lower dimension so that one can speak of weak form of NMP so that negentropy gain can be also below the maximal possible: we do not live in the best possible world. Second important ingredient is the notion of negentropic entanglement relying on p-adic norm.

The evolution of ideas related to NMP has been slow and tortuous process characterized by misinterpretations, over-generalizations, and unnecessarily strong assumptions, and has been basically evolution of ideas related to the anatomy of quantum jump and of quantum TGD itself.

Quantum measurement theory is generalized to theory of consciousness in TGD framework by replacing the notion of observer as outsider of the physical world with the notion of self. Hence it

is not surprising that several new key notions are involved.

1. ZEO is in central role and brings in a completely new element: the arrow of time changes in the counterpart of standard quantum jump involving the change of the passive boundary of CD to active and vice versa. In living matter the changes of the of time are inn central role: for instance, motor action as volitional action involves it at some level of self hierarchy.

2. The fusion of real physics and various p-adic physics identified as physics of cognition to single adelic physics is second key element. The notion of intersection of real and p-adic worlds (intersection of sensory and cognitive worlds) is central and corresponds in recent view about TGD to string world sheets and partonic 2-surfaces whose parameters are in an algebraic extension of rationals. By strong form of of holography it is possible to continue the string world sheets and partonic 2-surfaces to various real and p-adic surfaces so that what can be said about quantum physics is coded by them. The physics in algebraic extension can be continued to real and various p-adic sectors by algebraic continuation meaning continuation of various parameters appearing in the amplitudes to reals and various p-adics.

   An entire hierarchy of physics labeled by the extensions of rationals inducing also those of p-adic numbers is predicted and evolution corresponds to the increase of the complexity of these extensions. Fermions defining correlates of Boolean cognition can be said so reside at these 2-dimensional surfaces emerging from strong form of holography implied by strong form of general coordinate invariance (GCI).

   An important outcome of adelic physics is the notion of number theoretic entanglement entropy: in the defining formula for Shannon entropy logarithm of probability is replaced with that of p-adic norm of probability and one assumes that the p-adic prime is that which produces minimum entropy. What is new that the minimum entropy is negative and one can speak of negentropic entanglement (NE). Consistency with standard measurement theory allows only NE for which density matrix is n-dimensional projector.

3. Strong form of NMP states that state function reduction corresponds to maximal negentropy gain. NE is stable under strong NMP and it even favors its generation. Strong form of NMP would mean that we live in the best possible world, which does not seem to be the case. The weak form of NMP allows self to choose whether it performs state function reduction yielding the maximum possible negentropy gain. If n-dimensional projector corresponds to the maximal negentropy gain, also reductions to sub-spaces with $n-k$-dimensional projectors down to 1-dimensional projector are possible. Weak form has powerful implications: for instance, one can understand how primes near powers of prime are selected in evolution identified at basic level as increase of the complexity of algebraic extension of rationals defining the intersection of realities and p-adicities.

4. NMP gives rise to evolution. NE defines information resources, which I have called Akashic records - kind of Universal library. The simplest possibility is that under the repeated sequence of state function reductions at fixed boundary of CD NE at that boundary becomes conscious and gives rise to experiences with positive emotional coloring: experience of love, compassion, understanding, etc... One cannot exclude the possibility that NE generates a conscious experience only via the analog of interaction free measurement but this option looks un-necessary in the recent formulation.

5. Dark matter hierarchy labelled by the values of Planck constant $h_{eff} = n \times h$ is also in central role and interpreted as a hierarchy of criticalities in which sub-algebra of super-symplectic algebra having structure of conformal algebra allows sub-algebra acting as gauge conformal algebra and having conformal weights coming as n-ples of those for the entire algebra. The phase transition increasing h_{eff} reduces criticality and takes place spontaneously. This implies a spontaneous generation of macroscopic quantum phases interpreted in terms of dark matter. The hierarchies of conformal symmetry breakings with $n(i)$ dividing $n(i+1)$ define sequences of inclusions of HFFs and the conformal sub-algebra acting as gauge algebra could be interpreted in terms of measurement resolution.

   n-dimensional NE is assigned with $h_{eff} = n \times h$ and is interpreted in terms of the n-fold degeneracy of the conformal gauge equivalence classes of space-time surfaces connecting

two fixed 3-surfaces at the opposite boundaries of CD: this reflects the non-determinism accompanying quantum criticality. NE would be between two dark matter system with same h_{eff} and could be assigned to the pairs formed by the n sheets. This identification is important but not well enough understood yet. The assumption that p-adic primes p divide n gives deep connections between the notion of preferred p-adic prime, negentropic entanglement, hierarchy of Planck constants, and hyper-finite factors of type II_1.

6. Quantum classical correspondence (QCC) is an important constraint in ordinary measurement theory. In TGD QCC is coded by the strong form of holography assigning to the quantum states assigned to the string world sheets and partonic 2-surfaces represented in terms of super-symplectic Yangian algebra space-time surfaces as preferred extremals of Kähler action, which by quantum criticality have vanishing super-symplectic Noether charges in the sub-algebra characterized by integer n. Zero modes, which by definition do not contribute to the metric of "world of classical worlds" (WCW) code for non-fluctuacting classical degrees of freedom correlating with the quantal ones. One can speak about entanglement between quantum and classical degrees of freedom since the quantum numbers of fermions make themselves visible in the boundary conditions for string world sheets and their also in the structure of space-time surfaces.

NMP has wide range of important implications.

1. In particular, one must give up the standard view about second law and replace it with NMP taking into account the hierarchy of CDs assigned with ZEO and dark matter hierarchy labelled by the values of Planck constants, as well as the effects due to NE. The breaking of second law in standard sense is expected to take place and be crucial for the understanding of evolution.

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In the sequel the formulation of NMP and various ideas involved with NMP are discussed first. The formulation of NMP for hyper-finite factors is discussed in separate section. The last section considers some consequences of NMP discussed in more detail in various books.

The appendix of the book gives a summary about basic concepts of TGD with illustrations. There are concept maps about topics related to the contents of the chapter prepared using CMAP realized as html files. Links to all CMAP files can be found at `http://tgdtheory.fi/cmaphtml.html` [L1]. Pdf representation of same files serving as a kind of glossary can be found at `http://tgdtheory.fi/tgdglossary.pdf` [L2]. The topics relevant to this chapter are given by the following list.

- TGD inspired theory of consciousness [L4]
- Negentropy Maximization Principle [L3]
- Zero Energy Ontology (ZEO) [L5]

2 Basic Notions And Ideas Behind NMP

In the following the basic ideas and notions behind NMP as well as evolution of NMP are summarized. The first form of NMP was rather naive. There was no idea about the anatomy of quantum jump and NMP only stated that the allowed quantum jumps are such that the information gain of conscious experience measured by the reduction of entanglement entropy resulting in the reduction of entanglement between the subsystem of system and its complement is maximal. Later it became clear that quantum jump has a complex anatomy. The term quantum jump is still however used about the process in question.

2.1 Zero Energy Ontology

Zero energy ontology (ZEO) changes considerably the interpretation of the unitary process. In zero energy ontology (ZEO) quantum states are replaced with zero energy states defined as a superpositions of pairs of positive and negative energy states identified as counterparts of initial and final states of a physical event such as particle scattering. The matrix defining entanglement between positive and negative - christened as M-matrix - is the counterpart of the ordinary S-matrix but need not be unitary. It can be identified as a "complex square root" of density matrix expressible as a product of positive square root of diagonal density matrix and unitary S-matrix. Quantum TGD can be seen as defining a "square root" of thermodynamics, which thus becomes an essential part of quantum theory.

U-matrix is defined between zero energy states and cannot therefore be equated with the S-matrix used to describe particle scattering events. Unitary conditions however imply that U-matrix can be seen as a collection of M-matrices labelled by zero energy states so that the knowledge of U-matrix implies the knowledge of M-matrices. The unitarity conditions will be discussed later. A natural guess is that U is directly related to consciousness and the description of intentional actions. For positive energy ontology state function reduction to the opposite boundary of CD would serve as a state preparation for the next quantum jump: state preparation and reduction are therefore related by time reflection.

In ZEO state function preparation and reduction can be assigned to the positive and negative energy states defining the initial and final states of the physical event. The reduction of the time-like entanglement during the state function reduction process corresponds to the measurement of the scattering matrix. In the case of negentropic time-like entanglement the reduction process is not random anymore and the resulting dynamics is analogous to that of cellular automata providing a natural description of the dynamics of self-organization in living matter. This self-organization is also 4-dimensional in ZEO: this is of utmost importance in attempts to understand living matter.

According to standard quantum measurement theory state function reductions can take place repeatedly without any change in the state. In ZEO state function reduction to a given boundary of CD can occur repeatedly without changing the corresponding part of zero energy state but affecting the part at the opposite boundary. Superposition of CDs with different sizes is possible and one can assign to the second (active) boundary a wave function in the space of moduli, which include the proper time distance between the tips of CD and discrete boosts by a subgroup of Lorentz group leaving the tip of the fixed (passive) boundary invariant. This distance must increase in average

sense and this gives rise to the arrow of experienced time. Self can be identified as a sequence of quantum jumps reducing to same boundary of CD.

The simplest assumption is that there are sequences of repeated state function reductions leaving everything at the passive boundary of CD invariant. In the moduli space for active boundary (parametwrized by Lorentz boost leaving passive boundary invariant and integer shift for the proper time distance between the tips of CD given repeated reduction, which consist of a unitary evolution in the moduli space of CDs inducing delocalization followed by localization to a fixed CD.

ZEO leads to a precise identification of the subsystem at space-time level. General coordinate invariance (GCI) in 4-D sense means that 3-surfaces related by 4-D diffeomorphisms are physically equivalent. It is convenient to perform a gauge fixing by a introducing a natural choice for the representatives of the equivalence classes formed by diffeo-related 3-surfaces.

1. Light-like 3-surfaces identified as surfaces at which the Minkowskian signature of the induced space-time metric changes to Euclidian one - wormhole contacts- are excellent candidates in this respect. The intersections of these surfaces with the light-like boundaries of CD define 2-D partonic surfaces. Also the 3-D space-like ends of space-time sheets at the light-like boundaries of CDs are very natural candidates for preferred 3-surfaces.

2. The condition that the choices are mutually consistent implies effective 2-dimensionality, whose original formulation was as follows. The intersections of these surfaces defining partonic 2-surface plus the distribution of 4-D tangent spaces at its points define the basic dynamical objects with 4-D general coordinate invariance reduced to 2-dimensional one. This effective 2-dimensionality was clear from the very beginning but is only apparent since also the data about 4-D tangent space distribution is necessary to characterize the geometry of WCW and quantum states. The quantum descriptions in terms of 3-D light-like or space-like surfaces and even in terms of 4-D surfaces are equivalent but redundant descriptions. 4-D space-time is necessary for classical part of description necessary in order to perform and interpret quantum measurements. Holography defines the correspondence between quantal (2-D surfaces) and 4-D classical degrees of freedom in space-time interior.

3. The recent formulation of effective 2-dimensionality is slightly different. Partonic 2-surfaces and string world sheets at which the modes of the induced spinor field are localized by well-definedness of em charge define the basic entities of strong form of holography [K29]. Space-time surfaces can be determined as preferred extremals from these data assuming quantum criticality meaning that clasical super-symplectic Noether charges associated with the sub-algebra of super-symplectic algebra with conformal weights coming as n-ples of those for the full algebra vanish for them.

As far as consciousness is considered effective 2-dimensionality means holography and could relate to the fact that at least our visual experience is at least effectively 2-dimensional.

2.2 Fusion Of Real And P-Adic Physics

The fusion of real and p-adic physics to a larger structure has been a long standing challenge for TGD. The motivations come both from elementary particle physics and TGD inspired theory of consciousness. The basic idea is that various number fields are fused to a larger structure by gluing them along rationals and common algebraic numbers. The challenge is to imagine what quantum jump and NMP could mean in this framework. The first question is how the unitary process acts.

1. U-process acts in spinorial degrees of freedom of WCW (fermionic Fock space for a given 3-surface) and in WCW degrees of freedom (the space of partonic 2-surfaces roughly).

2. WCW should decompose to sectors corresponding to space-time surfaces in varioys number fields. This suggests strongly an adelic view [K36] in which reals and various p-adic number fields form a structure analogous to a Cartesian product. These number fields froming adele (`http://en.wikipedia.org/wiki/Adele_ring`) would have rationals in common. One can define adele also for any algebraic extension of rationals and now the algebraic extension is shared by the factors. This suggests that the various number fields are glued together

like pages of a book along common back defined by the algebraic extension. Thus one has something which is not quite the Cartesian product. The implication would be a hierarchy of algebraic extensions forming an evolutionary hierarchy.

3. If one would have Cartesian proeuct, the tensor product for the fermionic Fock spaces for corresponding sub-WCWs would at the first look very natural but would lead to a situation in which each sector would contain fermionic states separately. This does not look natural. Rather, the real space-time sheets should correspond to a sensory representation of the quantum state and p-adic space-time sheets to cognitive representations of one and the same thing [K36]. Hence fermions must be localized at the back of the book.

   Fermions are indeed localized at string world sheets and partonic 2-surfaces already from the well-definedness of em charges and also the equivalence of octonionic spinor structure with the ordinary one necessary for twistorialization demands this. Also the strong form of holography is consistent with the vision that the quantum dynamics is coded by the data at these 2-D surfaces. Classical physics would be 4-D and necessary for the physical testing and interpretation of the theory. Fermions would correspond to Boolean cognition in intersection of realities and p-adicities and would be number theoretically universal as already their anti-commutation relations suggest: also the quantal version of the anti-commutation relations is number theoretically universal in the algebraic extension of rationals.

4. What can one say about the U-matrix and its satellites M and S [K30]? The earlier vision was that the transitions between different number fields are possible. The construction of transition amplitudes for them - interpreted as amplitudes for the realization of intention represented as p-adic space-time sheet as action predicted as real space-time sheet - would be possible in the intersection but their continuation to different number fields does not seem to make sense: one should always chose on number field.

   In the intersection everything is number theoretically universal. Hence the only reasonable conclusion is that these matrices exist separately in each sector and co-incide in the intersection: this is very powerful constraint and means reduction to algebraic geometry. They would give different representations of one and same thing. p-Adic mass calculations would serve as an excellent example about the usefulness of the cognitive representations - p-adic arithmetics is extremely simple as compared to the real one and the number theoretical existence fixes the physics to a high degree. This would give extremely powerful constraints also the real U-matrix.

2.3 Dark Matter Hierarchy

The identification of dark matter as phases having large value of Planck constant [K22, K8, K5] led to a vigorous evolution of ideas. Entire dark matter hierarchy with levels labelled by increasing values of Planck constant is predicted, and in principle TGD predicts the values of Planck constant if physics as a generalized number theory vision is accepted [K8].

The original vision was that the hierarchy of Planck constants demands a generalization of quantum TGD. This would have required a generalization of the causal diamond $CD \times CP_2$, where CD is defined as an intersection of the future and past directed light-cones of 4-D Minkowski space M^4. It however became clear that the hierarchy of Planck constants labels a hierarchy of quantum criticalities characterized by sub-algebras of super-symplectic algebras possessing a natural conformal structure. The sub-algebra for which the conformal weights come as n-ples of those for the entire algebra is isomorphic to the full algebra and acts as a conformal gauge algebra at given level of criticality.

In particular, the classical symplectic Noether charges for preferred extremals connecting 3-surfaces at the ends of CD vanish. and this defines preferred extremal property. There would be n conformal gauge equivalence classes of preferred extremals which would correspond to n sheets of a covering of the space-time surface serving as base space. There is very close similarity with the Riemann surfaces. Therefore coverings would be generated dynamically and there is no need for actual coverings of the imbedding space.

The gauge degeneracy corresponds to the non-determinism associated with the criticality having interpretation in terms of non-determinism of Kähler action and with strong form of holography.

The extremely strong super-symplectic gauge conditions would guarantee that the continuation of string world sheets and partonic 2-surface to preferred extremals is possible at least for some value of p-adic prime. A good guess is that this is the case for the so called ramified primes associated with the algebraic extension in question. These ramified primes would characterize physical system and the weak form of NMP would allow to understand how p-adic length scale hypothesis follows [K36].

p-Adic continuations identifiable as imaginations would be due to the existence of p-adic pseudo-constants. The continuation could fail for most configurations of partonic 2-surfaces and string world sheets in the real sector: the interpretation would be that some space-time surfaces can be imagined but not realized [K17]. For certain extensions the number of realizable imaginations could be exceptionally large. These extensions would be winners in the number theoretic fight for survival and and corresponding ramified primes would be preferred p-adic primes.

A further strong prediction is that the phase transitions increasing h_{eff} and thus reducing criticality (TGD Universe is like hill at the top of the hill at....) occur spontaneously [K34]. This conforms with NMP and suggests that evolution occurs spontaneously. The state function reduction increasing h_{eff} means however the death of a sub-self so that selves are fighting to stay at the criticality. The metabolic energy bringing inNE allows to satisfy the needs of NMP so that the system survives and provides a garden in which subselves can are born and die and gradually generate negentropic entanglement. Living systems are thus negentropy gatherers and each death and re-incarnation generates new negentropy.

All particles in the vertices of Feynman diagrams have the same value of Planck constant so that the particles at different pages cannot have local interactions. Thus one can speak about relative darkness in the sense that only the interactions mediated by the exchange of particles and by classical fields are possible between different pages. Dark matter in this sense can be observed, say through the classical gravitational and electromagnetic interactions. It is in principle possible to photograph dark matter by the exchange of photons which leak to another page of book, reflect, and leak back. This leakage corresponds to h_{eff} changing phase transition occurring at quantum criticality and living matter is expected carry out these phase transitions routinely in bio-control. This picture leads to no obvious contradictions with what is really known about dark matter and to my opinion the basic difficulty in understanding of dark matter (and living matter) is the blind belief in standard quantum theory. These observations motivate the tentative identification of the macroscopic quantum phases in terms of dark matter and also of dark energy with gigantic "gravitational" Planck constant.

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

Dark matter could be a key player in quantum biology.

1. Dark matter hierarchy and p-adic length scale hierarchy would provide a quantitative formulation for the self hierarchy. To a given p-adic length scale one can assign a secondary p-adic time scale as the temporal distance between the tips of the CD. For electron this time scale is.1 second, the fundamental bio-rhythm. For a given p-adic length scale dark matter hierarchy gives rise to additional time scales coming as $h_{eff}/h = n$-multiples of this time scale.

2. The predicted breaking of second law of thermodynamics chacterizing living matter - if identified as something in the intersection of real and p-adic words - would be always below the time scale of CD considered but would take place in arbitrary long time scales at appropriate levels of the hierarchy. The scaling up of h_{eff} also scales up the time scale for the breaking of the second law.

3. The hypothesis that magnetic body is the carrier of dark matter in large h_{eff} phase has led to models for EEG predicting correctly the band structure and even individual resonance bands and also generalizing the notion of [J4] [K6]. Also a generalization of the notion of genetic code emerges resolving the paradoxes related to the standard dogma [K14, K6]. A particularly fascinating implication is the possibility to identify great leaps in evolution as phase transitions in which new higher level of dark matter emerges [K6].

2.4 Quantum Classical Correspondence

Quantum classical correspondence (QCI) has served as a guideline in the evolution of the ideas and the identification of the geometric correlates of various quantum notions at the level of imbedding space and space-time surfaces has been an important driving force in the progress of ideas.

1. In ZEO causal diamonds (CDs) identified roughly as intersections of future and past directed light-cones are in key role. At imbedding space level CD is a natural correlate for self and sub- CDs serve as correlates of sub-selves identified as mental images. At space-time level the space-time sheets having their ends at the light-like boundaries of CD serve as correlates for self. For a system characterized by a primary p-adic length scale $L_p \propto 2^{k/2}$ the size scale of CD is secondary p-adic scale $L_{p,2} = \sqrt{p}L_p \propto 2^k$. p-Adic length scale hypothesis follows if the proper time distance between the tips of CDs is quantized in powers of 2. This quantization should relate directly to almost equivalence of octaves associated with music experience. It must be emphasized that this assumption is very probably too strong. If the distances come as integer multiples of CP_2 time, the U-matrices form a structure analogous to Kac-Moody algebra: the role of conformal weights is taken by the distances. NMP indeed selects preferred p-adic primes and thus also size scales for CDs.

2. At the level of space-time the identification of flux tubes (I called them earlier flux tubes) between space-time sheets (more precisely, between partonic 2-surfaces) as a correlate for bound state entanglement suggests itself. Flux tubes correspond typically to magnetic flux tubes in the TGD inspired quantum model of living matter. The size scale of the magnetic body of system is given by the size scale of CD and much larger than the size of the system itself.

3. The space-time sheets in the intersection of the real and p-adic WCWs characterized by the property that the mathematical representation of the partonic 2-surfaces at the ends representing holograpically the state allows interpretation in both real and p-adic sense would correspond to the correlates for negentropic entanglement. Rational and algebraic 2-surfaces defined by partonic 2-surfaces and string world sheets (in preferred coordinates) would be the common points of realities and p-adicities.

Quantum classical correspondence allows also to generate new views about quantum theory itself. Many-sheeted space-time and p-adic length scale hierarchy force to generalize the notion of sub-system. The space-time correlate for the negentropic and bound state entanglement is the formation of flux tubes connecting two space-time sheets. The basic realization is that two disjoint space-time sheets can contain smaller space-time sheets topologically condensed at them and connected by flux tubes. Thus systems un-entangled at a given level of p-adic hierarchy - that is in the measurement resolution defined by the level considered - can contain entanglement subsystems at lower level not visible in the resolution used.

In TGD inspired theory of consciousness this makes possible sharing and fusion of mental images by entanglement. The resolution dependence for the notions of sub-system and entanglement means that the entanglement between sub-systems is not "seen" in the length scale resolution of unentangled systems. This phenomenon does not result as an idealization of theoretician but is a genuine physical phenomenon. Obviously this generalized view about sub-system poses further challenges to the detailed formulation of NMP. Note that the resulting mental image should depend on whether sub-selves are entangled by bound state entanglement or NE.

2.5 Connection With Standard Quantum Measurement Theory

TGD allows to deduce the standard quantum measurement theory involving the notion of classical variables and their correlation with quantum numbers in an essential manner. WCW ("world of classical worlds" is a union over zero modes labelling infinite-dimensional symmetric spaces having interpretation as classical non-quantum fluctuating classical variables such as the pointer of a measurement apparatus essential for the standard quantum measurement theory [K4]. Quantum holography in its origimnal form states that partonic 2-surfaces at the light-like boundaries of CDs plus the corresponding distributions of 4-D tangent spaces of space-time surfaces at carry the information about quantum state and space-time sheet. The recent formulation talks about partonic 2-surfaces and string world sheets intersection them at discrete points with string connecting partonic 2-surfaces and string boundaries at their orbits carrying fermion number. The distribution of values of induced Kähler form of CP_2 at these surfaces defines zero modes whereas quantum fluctuating degrees of freedom correspond to the deformations of space-time surface by the flows induced by Hamiltonians associated with the degenerate symplectic structure of $\delta M^4_{\pm} \times CP_2$.

There exists no well-defined metric integration measure in the infinite-dimensional space of zero modes, which by definition do not contribute to the line element of WCW. This does not lead to difficulties if one assumes that a complete localization in zero modes occurs in each quantum jump. A weaker condition is that wave functions are localized to discrete subsets in the space of zero modes. An even weaker and perhaps the most realistic condition is that a localization to a finite-dimensional 2n-dimensional manifold with induced symplectic form defining a positive definite integration volume takes place.

The fundamental formulation of quantum TGD in terms of the Kähler action and Kähler-Dirac action [K29, K9] containing measurement interaction terms guarantees quantum classical correspondence in the sense that the geometry of the space-time surface correlates with the values of conserved quantum numbers. The boundary term of Kähler-Dirac action (1-D massless Dirac action) implies that fermion line is light-like geodesic of $M^4 \times CP_2$ and carries light-like $M^4 \times E^4$ 8-momentum ($SO(4)$ quantum numbers when one uses partial wavs). The modes of imbedding space spinor field carry four momentum and color ($SU(3)$) quantum numbers are also massless in 8-D sense and if the two four-momenta are identical one has Equivalence Principle (EP). The mass squared in E^4 degrees of freedom equals to the eigenvalue of spinor Laplacian in CP_2 degrees of freedom. This defines a more abstract form of EP: $SO(4)$ quantum numbers label hadrons and $SU(3)$ quantum numbers quarks and gluons so that one has dual representations.

The resulting correlation of zero modes with the values of quantum numbers can be interpreted as an abstract form of quantum entanglement reduced in quantum jump for the standard definition of the entanglement entropy.

That state function can occur at both boundaries of CD localizing the boundary in question reducing the part of zero energy state associated with it is the new element of TGD inspired quantum measurement theory and allows to understand how the arrow of experienced time emerges and precisely define self - observer - as a part of system interacting with it. Also the possibility that the arrow of time changes at some level of the self hierarchy is predicted. In living matter this is expected to occur routinely as already Fantappie speculated [J6]: the first state function reduction in the sequence of them and changing the arrow of time is indeed naturally identified as a correlate for the volitional act.

2.6 Quantum Jump As Moment Of Consciousness

Quantum jump between quantum histories identified as moment of consciousness was originally believed to be something irreducible and structureless. Gradually the view about quantum jump has however become more and more structured and a connection with the standard quantum measurement theory emerged. In what sense quantum jumps remains irreducible is that one cannot build any dynamical model for the non-deterministic steps appearing in quantum jump.

2.6.1 The general structure of quantum jump

It seems that TGD involves "holy trinity" of dynamics.

1. The dynamics defined by the preferred extremals of Kähler action corresponds to the dynamics of material existence, with matter defined as "res extensa", three-surfaces. What preferred extremals really are has been a long standing open question. The recent formulation of the quantum theory using Kähler-Dirac action leads to the proposal that the preferred extremals are critical in the sense that they allow an infinite number of deformations for which the second variation vanishes. At the level of Kähler action this corresponds to the vanishing of classical Noether charges for a sub-algebra of super-symplectic algebra isomorphic with the entire algebra. This serves as space-time counterpart for quantum criticality of TGD Universe fixing the fundamental variational principle uniquely.

2. The dynamics defined by the sequence of state function reductions at fixed boundary of CD defining the life span of self at given level of hierarchy. This time evolution is a discrete counterpart of the ordinary Schrödinger time evolution $U \equiv U(-t,)$, $t \to \infty$ and can be regarded as "informational" time development occurring at the level of objective existence. It is un-necessary and in fact impossible to assign real Schrödinger time evolution with U. U defines the S-matrix of the theory. These reductions define the dynamics of sensory perception (passive aspects of consciousness) during which external world is regarded as unchanged in standard framework. Now the part of zero energy state at the fixed boundary of CD remains unchanged and un-entangled.

3. The dynamics of state function reductions at opposite boundary of CD defines the dynamics of volition (active aspects of consciousness).

Quantum jump was originally regarded as something totally irreducible. Gradually the structure of the complex formed by state function reductions and unitary process has revealed itself and led to the understanding how one can understand basic aspects of conscious experience in terms of this structure. Let us start with the original picture.

1. The first step in quantum jump was identified as "informational time development"

$$\Psi_i \to U\Psi_i \ ,$$

where U is the counterpart of the unitary process of Penrose. The resulting state is a completely entangled multiverse state, the entire sub-universe corresponding to a given CD being in a holistic state of "oneness".

In the recent picture Universe is replaced with CD and "informational time development" corresponds to a sequence of state function reductions keeping second boundary of CD and and states associated with it fixed. Repeated measurement having no effect on quantum state is the analog in standard quantum measurement theory. Self corresponds to this sequence.

Two subsequent reductions at same boundary of CD have unitary process between them tending to increase the size CD. The challenge is to identify the unitary process U. Self experiences the flow of time, which suggests that the unitary operator followed by localization in the moduli spaces of CDs corresponds to an integer shift for the tip of the active boundary of CD. No state function reduction can occur at the active boundary of CD during this period.

2. Next comes the TGD counterpart of state function in the ordinary sense of the word:

$$U\Psi_i \to \Psi_f^0 \ .$$

According to the recent view, the state function reduction in this sense corresponds to the state function at the opposite boundary of cD and leads to a change of the arrow of geometric time. Old self dies and new self is born. In this transition also the value of h_{eff} is expected to increase. This reduction is preceded by a scaling of by the integer ratio $h_{eff}(f)/h_{eff}(i)$ and realized as a unitary exponential of conformal scaling operator. Thus both Poincare and conformal time developments are realized.

3. The state function reduction for given CD is followed by a cascade of self measurements for sub-CDs in quantum fluctuating degrees of freedom

$$\Psi_f^0 \to .... \to \Psi_f \ ,$$

whose dynamics is governed by the Negentropy Maximization Principle (NMP). For a generic entanglement probabilities this process leads to bound states or negentropically entangled states. This process can be regarded as an analysis or even decay process. If entanglement probabilities define projection operator, the state function reduction leads or can laed to a negentropically entangled state: this depends on what form of NMP one assumes. Entanglement coefficients correspond to unitary matrix in this case.

Quantum measurement theory involves also the correlation between quantum degrees of freedom and classical degrees of freedom (the position of the pointer of the measurement apparatus correlates with the outcome of the measurement).

1. The assumption that localization occurs in zero modes of the WCW would pose very important consistency condition: there is one-one correlation between the quantum numbers in quantum fluctuating degrees of freedom in some state basis and the values of the zero modes. This in fact has interpretation in terms of holography: classical degrees of freedom in space-time interior correlate with fermionic degrees of freedom assignable to string world sheets and partonic 2-surfaces. This together with the fact that zero modes are effectively classical variables, implies that the localization in zero modes corresponds to a state function reduction.

2. Measurement theory requires an entanglement between zero modes and quantum jumps of the physical state. The addition of a measurement interaction term to the Kähler-Dirac action coupling to four-momentum and color quantum numbers of the state and also to more general conserved quantum numbers allows an explicit realization of this coupling and induces the addition of an analogous measurement interaction term to Kähler action [K29]. This term implies the entanglement of the quantum numbers of the physical states with zero modes.

A good metaphor for quantum jump is as Djinn leaving the bottle (informational time development), fulfilling the wish (quantum jump involving choice) and returning to, possibly new, bottle (localization in zero modes and subsequent state preparation process). One could formally regard each quantum jump as a quantum computation with duration defined by the life-time of corresponding self (the increase of the average temporal distance between the tips of CD in superposition of CDs) followed by halting meaning reduction to the opposite boundary of CD. Quantum jump to the opposite boundary could also be seen as an act of volition (or giving rise to experience of volition at some level of self hierarchy).

2.6.2 Is the complete localization in zero modes really necessary?

The detailed inspection of what happens in state function reductions forces to consider the possibility that state function reduction involves always a complete localization in zero modes. This was indeed the original proposal. It however seems that a localization modulo finite measurement resolution might be a more realistic assumption. Certainly it is enough to explain why the perceived Universe looks classical.

1. QFT picture strongly suggests that sub-system must be defined as a tensor factor of the space of WCW spinors at given point Y^3 of WCW . This suggests that subsystem should be defined as a function of Y^3 and should be a local concept. An important consequence of this definition is that entanglement entropy gives information about space-time geometry.

2. WCW spinor field can be formally expressed as superposition of quantum states localized into the reduced configuration space consisting of 3-surfaces belonging to light cone boundary. Hence WCW spinor field can be formally written as

$$\sum_{Y^3} C(Y^3)(n,N)|n\rangle|N\rangle$$

for any subsystem-complement decomposition defined in Y^3. Clearly, WCW coordinates appear in the role of additional indices with respect to which entanglement coefficients are diagonal. The requirement that final state is pure state would suggest that quantum jump reducing entanglement must involve complete localization of the WCW spinor field to some Y^3 plus further quantum jump reducing entanglement in Y^3. Complete localization in WCW is however not physically acceptable option since the action of various gauge symmetries on quantum states does not commute with the complete localization operation. In particular, the requirement that physical states belong to the representations of Super Virasoro and super-symplectic algebras, is not consistent with this requirement.

3. WCW has fiber space structure. WCW metric is non-vanishing only in the fiber degrees of freedom and since the propagator for small fluctuations equals to the contravariant metric, fiber degrees of freedom correspond to genuine quantum fluctuations. WCW metric vanishes in zero modes, which can be identified as fundamental order parameters in the spirit of Haken's theory of self organization. The requirement that various local symmetries act as gauge symmetries, provides good reasons to expect that *entanglement coefficients in the fiber degrees of freedom are gauge invariants and depend on the zero modes parametrically.* The one-one correlation between quantum numbers of the state assignable to fiber degrees of freedom and classical variables identified as zero modes would encourage the assumption the a complete localization occurs in zero modes. A weaker condition is that localization occurs only modulo a finite measurement resolution.

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

5. The time development by quantum jumps in zero modes is effectively classical: Universe is apparently hopping around in the space of the zero modes. This looks very attractive physically since zero modes characterize the size, shape and classical Kähler fields associated with 3-surface. Therefore each quantum jump gives very precise conscious geometric information about space-time geometry and about WCW in zero modes. This also means that Haken's classical theory of self-organization generalizes almost as such to TGD context. The probability for localization to given point of zero mode space is given by the reduced probability density Q defined by the integral of the probability density R defined by WCW spinor field over fiber degrees of freedom. The local maxima of Q with respect to zero modes appear as attractors for the time development by quantum jumps. Dissipative time development could be regarded as a sequence of quantum jumps leading to this kind of local maximum.

6. Effective localization in zero modes is completely analogous to spontaneous symmetry breaking in which scalar field attains vacuum expectation value with the difference that the number of degrees of freedom is infinite unlike in typical models of symmetry breaking. Thus the general structure of the WCW spinor field together with TGD based quantum jump concept automatically implies spontaneous symmetry breaking in its TGD version (note however that particle massivation results from both p-adic thermodynamics and coupling to Higgs like field of purely geometric origin in TGD framework). TGD Universe is superposition of parallel

classical universes (3-surfaces). Therefore quantum entangled state can can be regarded as a superposition of parallel entangled states, one for each 3-surface. Formally entanglement coefficients can be regarded as coefficients containing the WCW coordinates of 3-surfaces as additional index. The analogy with the spin glass also supports the localization in the zero modes.

7. Effective localization in the zero modes provides simple explanation for why the universe of conscious experience looks classical: moment of consciousness makes it classical. It also explains why the physics treating space-time as a fixed arena of dynamics has been so successful. As already found, a further important consequence is first principle description of the state function reduction.

2.7 NMP And Negentropic Entanglement

The evolution of NMP has been a process in which formulation has become gradually more accurate. The final outcome is surprisingly near to the original picture.

2.7.1 Information measures for entanglement

The attempts to formulate NMP in p-adic physics led to the realization that one can distinguish between three kinds of information measures.

1. In real physics the negative of the entanglement entropy defined by the standard Shannon formula defines a natural information measure, which is always non-positive. The formula for Shannon formula is given by $S = -\sum_n P_n log(P_n)$, where P_n are the probabilities identifiable as eigenvalues of the density matrix for a pair of system and its complement. Density matrix is defined as $\rho = C^{dagger}C$, C is the matrix defined by the entanglement coefficients for the system and its complement. In the original formulation of NMP the state function it was assumed that ρ defines the universal observable measured in state function reduction so that the sub-system (its complement) goes to an eigen state of ρ. This assumption is still kept.

2. In p-adic physics one can generalize entanglement entropy as (dis-)information measure to p-adic valued information measure by replacing the logarithms of p-adic valued probabilities with the p-based logarithms $log_p(|P|_p)$ which are integer valued and can be interpreted as p-adic numbers. This p-adic valued entanglement entropy can be mapped to a non-negative real number by the so called canonical identification $x = \sum_n x_n p^n \rightarrow \sum_n x_n p^{-n}$. In both cases a non-positive information measure results.

   When entanglement probabilities are rational numbers or at most finitely algebraically extended rational numbers one can still define logarithms of probabilities as p-based logarithms $log_p(|P|_p)$ and interpret the entropy as a rational or algebraic number. In this case the entropy can be however negative and positive definite information measure is possible. Irrespective of number field one can in this case define entanglement entropy as a maximum of number theoretic entropies S_p over the set of primes.

3. The consistency with quantum measurement theory forces to give up the most general identification of negentropic entanglement (NE). One could argue that it is not possible to distinguish between real and thus entropic entanglement and NE in any manner. One would need some signature for it. The internal consistency of quantum measurement theory indeed demands that the state function reduction occurs to an eigen space of density matrix, which in the most general case is characterized by an n-dimensional projector satisfying $P^2 = P$. Projector property of the final state density matriz would serve as a unique signature of negentropic entanglement.

It seems that the third choice is the correct one. NE would thus correspond to a density matrix proportional to a projector (identity matrix). What would be new that P is higher-dimensional projector. In real context one can argue that this situation is practically never met in reality. In TGD however hierarchy of Planck constants labelling quantum critical phases identified as dark matter would correspond to this kind of situations. Density matrix decomposes to a direct sum of

terms proportional to higher-D projectors only at criticality. The interpretation could be in terms of measurement resolution: experimental resolution does not allow to discern between the n state pairs in the superposition and their probabilities are identical.

NE would result in the case of 2-particle system from entanglement coefficients defining a unitary matrix. This strongly suggests that quantum computing systems carry NE.

There has been also the question about whether NE could be identified as bound state entanglement. It is obvious that this cannot be the case for NE defined by projector treating all entangled state pairs democratically.

2.7.2 Does entanglement negentropy have a classical space-time correlate?

Quantum classical correspondence (QCC) suggests that number theoretic entanglement negentropy or entropy could have a classical counterpart at space-time level. The interpretation of Kähler function as the analog of thermodynamical free energy with Kähler coupling strength playing the role of critical temperature leads to ask whether the Kähler function could define the counterpart of entanglement entropy or - negentropy. The standard formula for the entropy in terms of free energy suggests that entropy is positive also now, and the interpretation as entropy would look more natural. One must of course be very cautious: also the negative of Kähler function could be identified as the analog of free energy and in this case entropy would be negative.

Kähler function is identified as Kähler action in the region of space-time with Euclidian signature and is non-negative. Kähler function is not present in GRT like theories so that it is a new concept. It is not yet clear whether also the Euclidian regions correspond to n-sheeted coverings.

What happens in Minkowkian regions, where $\sqrt{g_4}$ is imaginary and Kähler function is replaced with the analog of Morse function? In Minkowskian regions Kähler action can have also negative sign. Could Kähler action in these regions have information theoretic interpretation? If so then the magnetic flux tubes would naturally correspond to negentropic regions and electric flux quanta to entropic ones. In Minkowskian regions magnetic flux tubes with $h_{eff} = n \times h$ correspond to n-fold coverings and give rise to n-fold value of Kähler action so that the interpretation in terms of negentropy might make sense. Note however that one can ask whether the flux tubes are actually Euclidian regions connecting Euclidian regions bounded by partonic 2-surfaces. This is possible since the string world sheet associated with the string like objects can have also Euclidian signature of metric.

An interesting question is how the negentropy assignable with the inclusions of hyperfinite factors and determined by the logarithm for the index of inclusion (to be discussed later) could relate to the value spectrum of Kähler function.

2.7.3 Bound state entanglement and NE

It is almost trivial that bound state entanglement must be kinematically stable against NMP became obvious. One can imagine that the state function reduction proceeds step by step by reducing the state to two parts in such a manner that the reduction of entanglement entropy is maximal.

1. If a resulting subsystem corresponds to a bound state having no decomposition to free subsystems the process stops for this subsystem. The natural assumption is that subsystems lose their consciousness when U process leads to bound state entanglement whereas bound state itself can be conscious.

2. If the entanglement is negentropic (and thus rational or algebraic) a more natural interpretation consistent with the teaching of spiritual practices is that subsystems experience a fusion to a larger conscious entity. The negentropic entanglement between free states is stabilized by NMP and negentropically entangled states need not reside at the bottom of potential well forbidding the reduction of entanglement. This makes possible new kinds of correlated states for which binding energy can be negative. Bound state entanglement would be like the jail of organized marriage and NE like a love marriage in which companions are free to leave but do not what it. The existence of this kind of NE is especially interesting in living matter, where metabolism (high energy phosphate bond in particular) and the stability of DNA and

other highly charged polymers is poorly understood physically: NE could be responsible for stabilization making possible the transfer of metabolic energy [K10].

2.7.4 Strong and weak forms of NMP

The *strong form of NMP* would state that negentropy of the universe is maximal in each state function reduction: we would live in the best possible world. This does not seem to be the case however. This leads to the *weak form of NMP* stating that in the case that maximal negentropy gain corresponds to n-dimensional projector, also the reductions to $n-k$-dimensional sub-spaces are possible and for $n-k=1$ one has ordinary reduction. Self can choose between different projector terms in ρ and for the chosen term choose lower- than maximal-dimensional sub-space.

The interpretation is that this brings to the theory of consciousness free will, ethics, and moral [K26]. Good means generation of NE, evolution. The choice in which outcome is 1-dimension sub-space means isolation, breaking of contact, as a punishment for not generating NE. The number of different choices in state function reduction for a given value of n is 2^n-1, which suggests am interpretation in terms of a Boolean algebra with n bits and an emotional realization of Boolean algebra - kind of emotional intelligence.

The weak form of NMP leads allows also to understand how preferred p-adic primes suggested by the p-adic length scale hypothesis emerged. The point is that NE per dimension of space is maximal when n is power of p. If n is power of p and $n-k$ is prime then the NE per dimension of subs-space is very large for it. For $p=2$ this would explained preferred role of Mersenne primes.

2.7.5 What if the eigenvalues of the density matrix go outside the algebraic extension used?

The following argument suggests that also more general algebraic entanglement could be reasonably stable against NMP, namely the entanglement for which the eigenvalues of the density matrix and eigenvectors are outside the algebraic extension associated with the parameters characterizing string world sheets and partonic 2-surfaces as space-time genes.

The restriction to a particular extension of rationals - a central piece of the number theoretical vision about quantum TGD - implies that density matrix need not allow diagonalization. In eigen state basis one would have has algebraic extension defined by the characteristic polynomial of the density matrix and its roots define the needed extension which could be quite well larger than the original extension. This would make state stable against state function reduction.

If this entanglement is algebraic, one can assign to it a negative number theoretic entropy. This negentropic entanglement is stable against NMP unless the algebraic extension associated with the parameters characterizing the parameters of string world sheets and partonic surfaces defining space-time genes is allowed to become larger in a state function reduction to the opposite boundary of CD generating re-incarnated self and producing eigenstates involving algebraic numbers in a larger algebraic extension of rationals. Could this kind of extension be an eureka experience meaning a step forwards in cognitive evolution?

If this picture makes sense, one would have both the unitary NE with a density matrix, which is projector and the algebraic NE with eigen values and NE for which the eigenstates of density matrix outside the algebraic extension associated with the space-time genes. Note that the entanglement characterized by a unitary matrix is "meditative" in the sense that any state basis is possible and therefore in this state of consciousness it is not possible to make distinctions. This strongly brings in mind koans of Zen buddhism. The more general algebraic entanglement could represent abstractions as rules in which the state pairs in the superposition represent the various instances of the rule.

2.7.6 Is NE experienced directly?

Does the NE at the passive boundary of CD give automatically rise to a conscious experience or must one "measure" it somehow?

1. The assumption that repeated state function reductions measure the NE and give rise to a conscious experience of it, looks natural. That NE is experienced consciously as an experience with a positive emotional coloring (love, compassion, understanding, experience of beauty,...)

looks rather natural assumption since a repeated measurement of this state is in question although only the state at the active boundary changes. This experience would correspond to that part of experience which defines experiencer as something stable and unchanging (the original proposal was that self is a subsystem able to remain un-entangled and thus having self identity). The changing part of the experience would come from the active boundary of CD and give rise to an experience about flow of time due to the average increase of the distance between the tips of CD. Self would correspond to sequence of repeated reductions and would die when the first reduction to the opposite boundary of CD would occur. This would be an re-incarnation of self as a new conscious entity.

2. An alternative view is that NE as such gives rise to a conscious experience only in what is known as interaction free experiment [B1]. This idea looks un-necessary in the proposed framework. Interaction free measurement would be too complex a process to appear at the fundamental level.

It has turned that interaction free measurement could read bits (but not qubits) and might be involved with long term memory recall and reading of sensory and cognitive representations. The values of bits would remain unaffected in the interaction free measurement at idealized limit.

1. Interaction free measurement for which Elizur-Weizman bomb tester is an excellent representation (see `https://en.wikipedia.org/wiki/ElitzurVaidman_bomb_tester`) involves ordinary state function reduction. The outcome of state function reduction tells whether the bomb can act as quantum measurement apparatus or not (is it active or not) and at idealized limit the state of bomb is not changed (it does not explode). The reading of bits from memory is possible if bit 1 (say) can take the role of active state of bomb and bit 0 that of dud. In the bomb tester model the measured state corresponds to a superposition of two photon paths such that the other one traverses the bomb and induces explosion if state function reduction to this path takes place. The reduction to the other path does not induce explosion.

2. Interaction free measurement is useful if the bit can be represented as active/passive dichotomy. Active/passive dichotomy can be indeed represented in very simple manner physically. One has two state system in which lower energy state can be excited to a long lived higher energy state by photon absorption. System in higher energy state is passive and that in lower energy state active.

2.7.7 What happens to h_{eff} during state function reduction sequence?

What happens to h_{eff} during state function reduction sequence. Does it increase so that self would "become wiser" as it becomes older?

The natural assumption is that the value of h_{eff} stays constant during the life cycle of self and by NMP h_{eff} increasing phase transitions tend to occur as self dies and re-incarnates at opposite boundary of CD. In this process a state would be selected from the superposition of states having negentropic entanglement at the active boundary of CD.

The original idea about correlation between age and wisdom is not however wrong. h_{eff} increasing phase transitions can however occur for the sub-selves of self defining mental images of self. To these one can assign sub-CDs. Hence one can say that NE assignable to a given CD increases also during the repeated state function reductions.

It looks rather natural to assume that self does its best to stay alive by trying to gather somehow the NE needed to satisfy the demands of NMP: the easy solution is to eat other living beings! This is achieved by metabolic energy which has interpretation in terms of a transfer of NE carried by nutrients. Homeostasis in turn is a collection of mechanisms helping to stay at criticality.

2.7.8 Negentropic entanglement, NMP, braiding and TQC

Negentropic entanglement for which number theoretic entropy characterized by p-adic prime is negative so that entanglement carries information, is in key role in TGD inspired theory of consciousness and quantum biology.

1. The key feature of 2-particle negentropic entanglement (see **Fig.** `http://tgdtheory.fi/appfigures/cat.jpg` or **Fig. ??** in the appendix of this book) is that density matrix is projector and thus proportional to unit matrix so that the assumption that state function reduction corresponds to the measurement of density matrix does not imply state function reduction to one-dimensional sub-space. This special kind of degenerate density matrix emerges naturally for the hierarchy $h_{eff} = n \times h$ interpreted in terms of a hierarchy of dark matter phases. I have already earlier considered explicit realizations of negentropic entanglement assuming that E is invariant under the group of unitary or orthogonal transformations (also subgroups of unitary group can be considered -say symplectic group). One can however consider much more general options and this leads to a connection with topological quantum computation (TQC).

2. Entanglement matrix E equal to $1/\sqrt{n}$ factor times unitary matrix U (as a special case orthogonal matrix O) defines a density matrix given by $\rho = UU^\dagger/n = Id_n/n$, which is group invariant. One has NE respected by state function reduction if NMP is assumed. This would give huge number of negentropically entangled states providing a representation for some unitary group or its subgroup (such as symplectic group). In principle any unitary representation of any Lie group would allow representation in terms of NE. In principle any unitary representation of any Lie group would allow a representation in terms of NE.

3. In physics as generalized number theory vision, a natural condition is that the matrix elements of E belong to the algebraic extension of p-adic numbers used so that discreted algebraic subgroups of unitary or orthogonal group are selected. This realizes evolutionary hierarchy as a hierarchy of p-adic number fields and their algebraic extensions, and one can imagine that evolution of cognition proceeds by the generation of negentropically entangled systems with increasing algebraic dimensions and increasing dimension reflecting itself as an increase of the largest prime power dividing n and defining the p-adic prime in question.

4. One fascinating implication is the ability of TGD Universe to emulate itself like Turing machine: unitary S-matrix codes for scattering amplitudes and therefore for physics and negentropically entangled subsystem could represent sub-matrix for S-matrix as rules representing "the laws of physics" in the approximation that the world corresponds to n-dimension Hilbert space. Also the limit $n \to \infty$ makes sense, especially so in the p-adic context where real infinity can correspond to finite number in the sense of p-adic norm. Here also dimensions n given as products of powers of infinite primes can be formally considered.

One can consider various restrictions on E.

1. In 2-particle case the stronger condition that E is group invariant implies that unitary matrix is identity matrix apart from an overall phase factor: $U = exp(i\phi)Id$. In orthogonal case the phase factor is ± 1. For n-particle NE one can consider group invariant states by using n-dimensional permutation tensor $\epsilon_{i_1,...i_n}$.

2. One can give up the group invariance of E and consider only the weaker condition that permutation is represented as transposition of entanglement matrix: $C_{ij} \to C_{ij}$. Symmetry/antisymmetry under particle exchange would correspond to $C_{ji} = \epsilon C_{ij}$, $\epsilon = \pm 1$. This would give in orthogonal case $OO^T = O^2 = Id$ and $UU^* = Id$ in unitary case.

   In the unitary case particle exchange could be identified as hermitian conjugation $C_{ij} \to C^*_{ji}$ and one would have $U^2 = Id$. Euclidian gamma matrices γ_i define unitary and hermitian generators of Clifford algebra having dimension 2^{2m} for $n = 2m$ and $n = 2m + 1$. It is relatively easy to verify that the squares of completely anti-symmetrized products of k gamma matrices representing exterior algebra normalized by factor $1/\sqrt{k!}$ are equal to unit matrix. For $k = n$ the anti-symmetrized product gives essentially permutation symbol times the product $\prod_k \gamma_k$. In this manner one can construct entanglement matrices representing negentropic bi-partite entanglement.

3. The possibility of taking tensor products $\epsilon_{ij..k...n}\gamma_i \otimes \gamma_j .. \otimes \gamma_k$ of k gamma matrices means that one can has also co-product of gamma matrices. What is interesting is that quantum groups important in topological quantum computation as well as the Yangian algebra associated with

twistor Grassmann approach to scattering amplitudes possess co-algebra structure. TGD leads also to the proposal that this structure plays a central role in the construction of scattering amplitudes. Physically the co-product is time reversal of product representing fusion of particles.

4. One can go even further. In 2-dimensional QFTs braid statistics replaces ordinary statistics. The natural question is what braid statistics could correspond to at the level of NE. Braiding matrix is unitary so that it defines NE. Braiding as a flow replaces the particle exchange and lifts permutation group to braid group serving as its infinite covering.

   The allowed unitary matrices representing braiding in tensor product are constructed using braiding matrix R representing the exchange for two braid strands? The well-known Yang-Baxter equation for R defined in tensor product as an invertible element (`http://en.wikipedia.org/wiki/YangBaxter_equation`) expresses the associativity of braiding operation. Concretely it states that the two braidings leading from 123 to 321 produce the same result. Entanglement matrices constructed R as basic operation would correspond to unitary matrices providing a representation for braids and each braid would give rise to one particular NE.

   This would give a direct connection with TQC for which the entanglement matrix defines a density matrix proportional to $n \times n$ unit matrix: R defines the basic gate [B7]. Braids would provide a concrete space-time correlate for NE giving rise to "Akashic records". Note that in string theory-GRT framework this old idea of TGD has been recently introduced by Maldacena and Sussking as a proposal that wormholes connecting blackholes provide a description of entanglement.

   I have indeed proposed the interpretation of braidings as fundamental memory representations much before the vision about Akashic records. This kind of entanglement matrix need not represent only time-like entanglement but can be also associated also with space-like entanglement. The connection with braiding matrices supports the view that magnetic flux tubes are carriers of negentropically entangled matter and also suggests that this kind of entanglement between -say- DNA and nuclear or cell membrane gives rise to TQC.

Some comments concerning the covering space degrees of freedom associated with $h_{eff} = n \times h$ viz. ordinary degrees of freedom are in order.

1. Negentropic entanglement with n entangled states would correspond naturally to $h_{eff} = n \times h$ and is assigned with "many-particle" states, which can be localized to the sheets of covering but one cannot exclude similar entanglement in other degrees of freedom. Group invariance leaves only group singlets and states which are not singlets are allowed only in special cases. For instance for $SU(2)$ the state $|j, m\rangle = |1, 0\rangle$ represented as 2-particle state of 2 spin 1/2 particles is negentropically entangled whereas the states $|j, m\rangle = |1, \pm 1\rangle$ are pure.

2. Negentropic entanglement associated with $h_{eff} = n \times h$ could factorize as tensor product from other degrees of freedom. Negentropic entanglement would be localised to the covering space degrees of freedom but there would be entropic entanglement in the ordinary degrees of freedom - say spin. The large value of h_{eff} would however scale up the quantum coherence time and length also in the ordinary degrees of freedom. For entanglement matrix this would correspond to a direct sum proportional to unitary matrices so that also density matrix would be a direct sum of matrices $p_n E_n = p_n Id_n/n$, $\sum p_n = 1$ correspond ing to various values of "other quantum numbers", and state function reduction could take place to any subspace in the decomposition. Also more general entanglement matrices for which the dimensions of direct summands vary, are possible.

3. One can argue that NMP in form does not allow halting of quantum computation. This is not true. The computation halts but in different manner since negentropic entanglement tends to be generated even for weak form of NMP. Weak form of NMP allows also ordinary state function reduction. State function reduction is not need if NE can be directly experienced and self represents this mental image as a kind of abstraction or rule with the state pairs in the superposition representing the instances of the rule.

It might be also possible to deduce the structure of negentropically entangled state by an interaction free quantum measurement replacing the state function reduction with "externalised" state function reduction. One could speak of interaction free TQC. This TQC would be reading of "Akashic records".

4. One could also counter argue that NMP allows the transfer of NE from the system so that TQC halts. NMP allows this if some another system receives at least the negentropy contained by NE. The interpretation would be as the increase of information obtained by a conscious observer about the outcome of halted quantum computation.

   Metabolism could quite concretely correspond the transfer of NE associated with the NE between nutrient molecules and some system. This would satisfy the demands of NMP and make possible for the organism to avoid the first state function reduction to the opposite boundary of CD (death) In [K35] it is suggested that this system can be of astrophysical size, say gravitational Mother Gaia with magnetic flux tubes characterized by gravitational Planck constant $\hbar_{gr} = GMm/v_0 = \hbar_{eff} = n \times \hbar$, where v_0 is a parameter with dimensions of velocity. There is experimental evidence for dark matter shell around Earth [K22] and there are highly interesting connection to the hypothesis identifying bio-photons as decay products of dark photons located at magnetic flux tubes and having $h_{eff} = h_{gr}$.

2.7.9 The relationship to thermodynamics

The relationship with the ordinary thermodynamics is very interesting and my views about this have been fluctuating.

1. The basic point to notice is that entanglement (neg)entropy characterize the relationship of the system to its environment whereas thermodynamical entropy characterizes single particle in an ensemble. Hence these quantities are not directly comparable and NMP need not be in conflict with the second law. Ordinary state function reductions for an ensemble of systems lead to a generation of thermodynamical entropy and this explains the second law of thermodynamics in the sector consisting of visible matter $h_{eff} = h$ provided that phase transitions generating negentropic entanglement and transforming ensembles to quantum coherent states are not too probable.

2. For the NE the outcome of the state function reduction ceases to be completely random as it is for the standard definition of entanglement entropy. For the strong form of NMP the outcome seems rather unique: the degenerate subspace for which number theoretic negentropy is maximal. For the weak form of NMP there is an additional randomness - one might speak about analog of thermodynamical fluctuations. The average increase of negentropy is positive if various choices for the dimension $n - k$ of the subspace are equally probable. Usually life is seen as a thermodynamical fluctuations, now its analog would prevent the world to be the best possible one.

   It can happen that the generation of NE transforms thermodynamical ensemble to a superposition of negentropically entangled subsystems and next state function reduction to the opposite boundary generates a negentropically entangled state. This could lead to the breaking of second law. The generation of NE means also phase transitions generating dark matter at magnetic flux tubes assumed to serve as correlates for entanglement. Since dark matter is not visible using the recent measurement technology, the breaking of second law could remain unseen. This could provide a new view to understand self-organization [K21] and evolution in living systems in which dark matter plays a key role according to the TGD inspired vision.

3. This suggests a weak formulation of the second law. In any process in which dark matter possibly created by phase transitions is observed by transforming it to ordinary matter second law holds true since the decay of dark matter to ordinary matter destroys macroscopic quantum coherence. If it is possible to develop technologies allowing to observe dark matter without this transformation, second law does not hold in the observable Universe. The decay of dark photons to ordinary photons identified as bio-photons would represent one example of this. Note also that one can transform only a small sample of dark matter to visible matter.

By a book-keeping one can detect whether ordinary matter has transformed to dark matter and with some theory can deduce by taking this kind of samples about the distribution of dark matter.

2.7.10 NMP in adelic approach and two interpretational problems

There have been considerable progress in the understanding of NMP in Zero Energy Ontology (ZEO) and the latest progress is discussed in detail in [K41]. In adelic approach real and various p-adic sectors are combined to adelic structure at space-time level. State space is shared by all adelic sectors and corresponds to Hilbert space with a coefficient field, which is some extension of rationals. It defines an extension of p-adic numbers for all values of p. Algebraic extensions and also extensions by roots of e correspond to finite-dimensional extensions of p-adic numbers. Together these extensions define an adele.

At the level of WCW this means that the general coordinate - and Lorentz invariant coordinates of WCW have values in the algebraic extension making sense in all number fields. Strong form of holography means that string world sheets and partonic 2-surfaces (2-surfaces) serve as "space-time genes" determining the 4-D space-time surfaces so that these conformally invariant moduli parameters for these 2-surfaces serve as WCW coordinates.

In given p-adic sector entanglement entropy (EE) is defined by replacing the logarithms of probabilities in Shannon formula by the logarithms of their p-adic norms. The resulting entropy satisfies the same axioms as ordinary entropy but makes sense only for probabilities, which must be rational valued or in an algebraic extension of rationals. The algebraic extensions corresponds to the evolutionary level of system and the algebraic complexity of the extension serves as a measure for the evolutionary level. p-Adically also extensions determined by roots of e can be considered. What is so remarkable is that the number theoretic entropy can be negative.

A simple example allows to get an idea about what is involved. If the entanglement probabilities are rational numbers $P_i = M_i/N$, $\sum_i M_i = N$, then the primes appearing as factors of N correspond to a negative contribution to the number theoretic entanglement entropy and thus to information. The factors of M_i correspond to negative contributions. For maximal entanglement with $P_i = 1/N$ in this case the EE is negative. The interpretation is that the entangled state represents quantally concept or a rule as superposition of its instances defined by the state pairs in the superposition. Identity matrix means that one can choose the state basis in arbitrary manner and the interpretation could be in terms of "enlightened" state of consciousness characterized by "absence of distinctions". In general case the basis is unique.

Metabolism is a central concept in biology and neuroscience. Usually metabolism is understood as transfer of ordered energy and various chemical metabolites to the system. In TGD metabolism could be basically just a transfer of NE from nutrients to the organism. Living systems would be fighting for NE to stay alive (NMP is merciless!) and stealing of NE would be the fundamental crime.

TGD has been plagued by a longstanding interpretational problem: can one apply the notion of number theoretic entropy in the real context or not. If this is possible at all, under what conditions this is the case? How does one know that the entanglement probabilities are not transcendental as they would be in generic case? There is also a second problem: p-adic Hilbert space is not a well-defined notion since the sum of p-adic probabilities defined as moduli squared for the coefficients of the superposition of orthonormal states can vanish and one obtains zero norm states.

These problems disappear if the reduction occurs in the intersection of reality and p-adicities since here Hilbert spaces have some algebraic number field as coefficient field. By SH the 2-D states states provide all information needed to construct quantum physics. In particular, quantum measurement theory.

1. The Hilbert spaces defining state spaces has as their coefficient field always some algebraic extension of rationals so that number theoretic entropies make sense for all primes. p-Adic numbers as coefficients cannot be used and reals are not allowed. Since the same Hilbert space is shared by real and p-adic sectors, a given state function reduction in the intersection has real and p-adic space-time shadows.

2. State function reductions at these 2-surfaces at the ends of CD take place in the intersection of realities and p-adicities if the parameters characterizing these surfaces are in the algebraic

extension considered. It is however not absolutely necessary to assume that the coordinates of WCW belong to the algebraic extension although this looks very natural.

3. NMP applies to the total EE. It can quite well happen that NMP for the sum of real and p-adic entanglement entropies does not allow ordinary state function reduction to take place since p-adic negative entropies for some primes would become zero and net negentropy would be lost. There is competition between real and p-adic sectors and p-adic sectors can win! Mind has causal power: it can stabilize quantum states against state function reduction and tame the randomness of quantum physics in absence of cognition! Can one interpret this causal power of cognition in terms of intentionality? If so, p-adic physics seems be also physics of intentionality as originally assumed.

   One could also say that Einstein was rather near to truth when he said that God does not play dice. Conscious entities play dice only whey they die and re-incarnate as time-revered selves at the opposite boundary of CD - that is perform the first state function reduction at the opposite boundary of CD.

2.8 Wigner's friend and Schrödinger's cat

I encountered in Facebook discussion Wigner's friend paradox (see`http://tinyurl.com/jpnvtp5` and `http://tinyurl.com/ze6bmem`). Wigner leaves his friend to the laboratory together with Schrödinger's cat and the friend measures the state of cat: the outcome is "dead" or "alive". Wigner returns and learns from his friend what the state of the cat is. The question is: was the state of cat fixed already earlier or when Wigner learned it from his friend. In the latter case the state of friend and cat would have been superposition of pairs in which cat was alive and friend new this and cat was dead also now friend new this. Entanglement between cat and bottle would have been transferred to that between cat+bottle and Wigner's friend. Recall that this kind of information transfer occur in quantum computation and quantum teleportation allows to transfer arbitrary quantum state but destroys the original.

The original purpose of Wigner was to demonstrate that consciousness is involved with the state function collapse.

TGD view is that the state function collapse can be seen as moment consciousness [K16, K1]. Or more precisely, self as conscious entity corresponds to a repeated state function reduction sequence to the same boundary of causal diamond (CD). One might say that self is generalized Zeno effect in Zero Energy Ontology (ZEO). The first reduction to the opposite boundary of CD means death of self and re-incarnation at opposite boundary as time reversed self. The experiencet flow of time corresponds to the shift of the non-fixed boundary of self reduction by reduction farther from the fixed boundary - also the state at it changes. Thus subjective time as sequence of reductions is mapped to clock time identifiable as the temporal distance between the tips of CD. Arrow of time is generated but changes in death-reincarnation.

In TGD inspired theory of consciousness the intuitive answer to the question of Wigner looks obvious. If the friend measured the state of cat, it was indeed dead or alive already before Wigner arrived. What remains is the question what it means for Wigner, the "ultimate observer", to learn about the state of the cat from his friend. The question is about what conscious communications are.

Consider first the situation in the framework of standard quantum information theory.

1. Quantum teleportation (see `http://tinyurl.com/omfkydh`) could make it possible to transfer arbitrary quantum state from the brain of Wigner's friend to Wigner's brain. Quantum teleportation involves generation of Bell state (see `http://tinyurl.com/z9g8rar` of qubits assignable with Wigner's friend (A) and Wigner (B).

2. This quantum state can be constructed by a joint measurement of component of spin in same direction at both A and B. One of the four eigenstates of (by convention) the operator $Q^z = J_x^{1)} \otimes J_y^{2)} - J_y^{1)} \otimes J_x^{2)}$ is the outcome. For spinors the actions of J_x and J_y change the sign of J_z eigenvalue so that it becomes possible to construct the Bell states as eigenstates of Q^z.

3. After that Wigner's friend measures both the qubit representing cat's state, which is to be communicated and the qubit at A. The latter measurement does not allow to predict the state at B. Wigner's friend communicates the two bits resulting from this measurement to Wigner classically. On basis of these two classical bits his friend performs some unitary operation to the qubit at his end and transforms it to qubit that was to be communicated.

This allows to communicate the qubit representing measurement outcome (alive/dead). But what about meaning? What guarantees that the meaning of the bit representing the state of the cat is the same for Wigner and his friend? One can also ask how the joint measurement can be realized: its seems to require the presence of system containing $A \otimes B$. To answer these questions one must introduce some notions of TGD inspired theory of consciousness: self hierarchy and subself=mental image identification.

TGD inspired theory of consciousness predicts that during communication Wigner and his friend form a larger entangled system: this makes possible sharing of meaning. Directed attention means that subject and object are entangled. The magnetic flux tubes connecting the two systems would serve as a correlate for the attention. This mechanism would be at work already at the level of molecular biology. Its analog would be wormholes in ER-EPR corresponence proposed by Maldacena and Susskind. Note that directed attention brings in mind the generation of the Bell entangled pair A-B. It would make also possible quantum teleportation.

Wigner's friend could also symbolize the "pointer of the measurement apparatus" constructed to detect whether cats are dead of alive. Consider this option first. If the pointer is subsystem defining subself of Wigner, it would represent mental image of Wigner and there would be no paradox. If qubit in the brain in the brain of Wigner's friend replaces the pointer of measurement apparatus then during communication Wigner and his friend form a larger entangled system experiencing this qubit. Perhaps this temporary fusion of selves allows to answer the question about how common meaning is generated. Note that this would not require quantum teleportation protocol but would allow it.

Negentropically entangled objects are key entities in TGD inspired theory of consciousness and the challenge is to understand how these could be constructed and what their properties could be. These states are diametrically opposite to unentangled eigenstates of single particle operators, usually elements of Cartan algebra of symmetry group. The entangled states should result as eigenstates of poly-local operators. Yangian algebras involve a hierarchy of poly-local operators, and twistorial considerations inspire the conjecture that Yangian counterparts of super-symplectic and other algebras made poly-local with respect to partonic 2-surfaces or end-points of boundaries of string world sheet at them are symmetries of quantum TGD [K38]. Could Yangians allow to understand maximal entanglement in terms of symmetries?

1. In this respect the construction of maximally entangled states using bi-local operator $Q^z = J_x \otimes J_y - J_x \otimes J_y$ is highly interesting since entangled states would result by state function. Single particle operator like J_z would generate un-entangled states. The states obtained as eigenstates of this operator have permutation symmetries. The operator can be expressed as $Q^z = f^z_{ij} J^i \otimes J^j$, where f^A_{BC} are structure constants of SU(2) and could be interpreted as co-product associated with the Lie algebra generator J^z. Thus it would seem that unentangled states correspond to eigenstates of J^z and the maximally entangled state to eigenstates of co-generator Q^z. Kind of duality would be in question.

2. Could one generalize this construction to n-fold tensor products? What about other representations of SU(2)? Could one generalize from SU(2) to arbitrary Lie algebra by replacing Cartan generators with suitably defined co-generators and spin 1/2 representation with fundamental representation? The optimistic guess would be that the resulting states are maximally entangled and excellent candidates for states for which negentropic entanglement is maximized by NMP [K16].

3. Co-product is needed and there exists a rich spectrum of algebras with co-product (quantum groups, bialgebras, Hopf algebras, Yangian algebras). In particular, Yangians of Lie algebras are generated by ordinary Lie algebra generators and their co-generators subject to constraints. The outcome is an infinite-dimensional algebra analogous to one half of Kac-Moody algebra with the analog of conformal weight N counting the number of

tensor factors. Witten gives a nice concrete explanation of Yangian [B4] for which co-generators of T^A are given as $Q^A = \sum_{i<j} f^A_{BC} T^B_i \otimes T^C_j$, where the summation is over discrete ordered points, which could now label partonic 2-surfaces or points of them or points of string like object (see `http://arxiv.org/abs/hep-th/0401243`). For a practically totally incomprehensible description of Yangian one can look at the Wikipedia article (see `https://en.wikipedia.org/wiki/Yangian`).

4. This would suggest that the eigenstates of Cartan algebra co-generators of Yangian could define an eigen basis of Yangian algebra dual to the basis defined by the totally unentangled eigenstates of generators and that the quantum measurement of poly-local observables defined by co-generators creates entangled and perhaps even maximally entangled states. A duality between totally unentangled and completely entangled situations is suggestive and analogous to that encountered in twistor Grassmann approach where conformal symmetry and its dual are involved. A beautiful connection between generalization of Lie algebras, quantum measurement theory and quantum information theory would emerge.

3 Generalization Of NMP To The Case Of Hyper-Finite Type II_1 Factors

The intuitive notions about entanglement do not generalize trivially to the context of relativistic quantum field theories as the rigorous algebraic approach of [C1] based on von Neumann algebras demonstrates. von Neumann algebras can be written as direct integrals of basic building blocks referred to as factors [A4]. Factors can be classified to three basic types labelled as type I, II, and III. Factors of type I appear in non-relativistic quantum theory whereas factors of type III_1 in relativistic QFT [C1]. Factors of type II_1 [A3], believed by von Neumann to be fundamental, appear naturally in TGD framework [K28].

3.1 Factors

3.1.1 Factors of type I

The von Neuman factors of type I correspond to the algebras of bounded operators in finite or infinite-dimensional separable Hilbert spaces. In the finite-dimensional case the algebra reduces to the ordinary matrix algebra in the finite-dimensional case and to the algebra of bounded operators of a separable Hilbert space in the infinite-dimensional case. Trace is the ordinary matrix trace. The algebra of projection operators has one-dimensional projectors as basic building blocks (atoms), the notion of pure state is well-defined, and the decomposition of entangled state to a superposition of products of pure states is unique. This case corresponds to the ordinary non-relativistic quantum theory. Ordinary quantum measurement theory and also the theory of quantum computation has been formulated in terms of type I factors. Also the discussion of NMP has been formulated solely in terms of factors of type I.

3.1.2 Factors of type II_1

The so called hyper-finite type II_1 factors, which are especially natural in TGD framework, can be identified in terms of the Clifford algebra of an infinite-dimensional separable Hilbert space such that the unit operator has unit trace. Essentially the fermionic oscillator operator algebra associated with a separable state basis is in question. The theory of hyper-finite type II_1 factors is rich and has direct connections with conformal field theories [A6], quantum groups [A1], knot and 3-manifold invariants [A5, A2, A7], and topological quantum computation [K27], [B5].

3.1.3 Factors of type III

For algebras of type III associated with non-separable Hilbert spaces all projectors have infinite trace so that the very notion of trace becomes obsolete. The factors of type III_1 are associated with quantum field theories in Minkowski space.

The highly counter-intuitive features of entanglement for type III factors are discussed in [C1].

1. The von Neumann algebra defined by the observables restricted to an arbitrary small region of Minkowski space in principle generates the whole algebra. Expressed in a more technical jargon, any field state with a bound energy is cyclic for each local algebra of observables so that the field could be obtained in entire space-time from measurements in an arbitrary small region of space-time. This kind of quantum holography looks too strong an idealization.

   In TGD framework the replacement of Minkowski space-time with space-time sheet seems to restrict the quantum holography to the boundaries of the space-time sheet. Furthermore, in TGD framework the situation is nearer to the non-relativistic one since Poincare transformations are not symmetries of space-time and because 3-surface is the fundamental unit of dynamics. Also in TGD framework M^4 cm degrees of 3-surfaces are present but it would seem that they appear as labels of type II_1 factors in direct integral decomposition rather than as arguments of field operators.

2. The notion of pure state does not make sense in this case since the algebra lacks atoms and projector traces do not define probabilities. The generalization of the notion of pure state as in II_1 case does not make sense since projectors have infinite trace.

3. Entanglement makes sense but has very counter-intuitive properties. First of all, there is no decomposition of density matrix in terms of projectors to pure states nor any obvious generalization of pure states. There exists no measure for the degree of entanglement, which is easy to understand since one cannot assign probabilities to the projectors as their traces.

4. For any pair of space-like separated systems, a dense set of states violates Bell inequalities so that correlations cannot be regarded as classical. This is in a sharp contrast with elementary quantum mechanics, where "de-coherence effects" are believed to drive the states into a classically correlated states.

5. No local measurement can remove the entanglement between a local system and its environment. In TGD framework local operations would correspond to operations associated with a given space-time sheet. Irreducible type II_1 entanglement between different space-time sheets, if indeed present, might have an interpretation in terms of a finite resolution at state space level due to spin glass degeneracy.

On basis of these findings, one might well claim that the axiomatics of relativistic quantum field theories is not consistent with the basic physical intuitions.

3.2 NMP Hyper-Finite Factors Of Type II_1

In the following hyper-finite factors of type II_1 (HFFs) will be discussed since they are certainly emerge in TGD as operator algebra defined by the fermionic oscillator operators.

3.2.1 The origin of hyper-finite factors of type $\mathbf{II}_1$ in TGD

Infinite-dimensional Clifford algebra corresponds in TGD framework to the super-algebra generated by complexified WCW gamma matrices creating WCW spinor s from vacuum spinor which is the counterpart of Fock vacuum [K28]. By super-conformal symmetry also WCW degrees of freedom correspond to a similar factor. For type hyper-finite II_1 factors the trace is by definition finite and normalized such that the unit operator has unit trace. As a consequence, the traces of projection operators have interpretation as probabilities.

Finite-dimensional projectors have vanishing traces so that the notion of pure state must be generalized. The natural generalization is obvious. Generalized pure states correspond to states for which density matrix reduces to a projector with a finite norm. The physical interpretation is that physical measurements are never able to resolve completely the infinite state degeneracy identifiable in TGD framework as spin glass degeneracy basically caused by the vacuum degeneracy implying non-determinism of Kähler action. An equivalent interpretation is in terms of state space resolution, which can never be complete.

In TGD framework the relevant algebra can also involve finite-dimensional type I factors as tensor factors. For instance, the entanglement between different space-time sheets could be of

this kind and thus completely reducible whereas the entanglement in configuration space spin and "vibrational" degrees of freedom (essentially fermionic Fock space) would be of type II_1. The finite state-space resolution seems to effectively replace hyper-finite type II_1 factors with finite-dimensional factors of type I.

3.2.2 Hyper-finite factors of type $\mathbf{II}_1$ and quantum measurement theory with a finite measurement resolution

The realization that the von Neumann algebra known as hyper-finite factor of type II_1 is tailor made for quantum TGD has led to a considerable progress in the understanding of the mathematical structure of the theory and these algebras provide a justification for several ideas introduced earlier on basis of physical intuition.

Hyper-finite factor of type II_1 has a canonical realization as an infinite-dimensional Clifford algebra and the obvious guess is that it corresponds to the algebra spanned by the gamma matrices of WCW. Also the local Clifford algebra of the imbedding space $H = M^4 \times CP_2$ in octonionic representation of gamma matrices of H is important and the entire quantum TGD emerges from the associativity or co-associativity conditions for the sub-algebras of this algebra which are local algebras localized to maximal associative or co-associate sub-manifolds of the imbedding space identifiable as space-time surfaces.

The notion of inclusion for hyper-finite factors provides an elegant description for the notion of measurement resolution absent from the standard quantum measurement theory.

1. The included sub-factor creates in ZEO states not distinguishable from the original one and the formally the coset space of factors defining quantum spinor space defines the space of physical states modulo finite measurement resolution.

2. The quantum measurement theory for hyperfinite factors differs from that for factors of type I since it is not possible to localize the state into single ray of state space. Rather, the ray is replaced with the sub-space obtained by the action of the included algebra defining the measurement resolution. The role of complex numbers in standard quantum measurement theory is taken by the non-commutative included algebra so that a non-commutative quantum theory is the outcome.

3. This leads also to the notion of quantum group. For instance, the finite measurement resolution means that the components of spinor do not commute anymore and it is not possible to reduce the state to a precise eigenstate of spin. It is however perform a reduction to an eigenstate of an observable which corresponds to the probability for either spin state.

4. For HFFs the dimension of infinite-dimensional state space is finite and qual to $D = 1$ by convention. For included HFF $\mathcal{N} \subset \mathcal{M}$ the dimension of the tensor factor space containing only the degrees of freedom which are above measurement resolution is given by the index of inclusion $d = \mathcal{M} : \mathcal{N}$. One can say that the dimension associated with degrees of freedom below measurement resolution is $D = 1/d$. This number is never large than 1 for the inclusions and contains a set of discrete values $d = 4cos^2(2\pi/n)$, $n \geq 3$, plus the continuum above it. The fractal generalization of the formula for entanglement entropy gives $S = -log(1/D) = -log(d) \leq 0$ so that one can say that the entanglement negentropy assignable to the projection operators to the sub-factor is positive except for $n = 3$ for which it vanishes. The non-measured degrees of freedom carry information rather than entropy.

5. Clearly both HFFs of type I and II allow entanglement negentropy and allow to assign it with finite measurement resolution. In the case of factors its is not clear whether the weak form of NMP allows makes sense. Could the density matrix be expressed as a direct sum of projectors to subspaces multiplied by corresponding probabilities? Whether this is possible, is far from clear to me: in any case it would require new mathematics.

   A more natural looking option is that the decomposition of the density matrix to projectors is replaced with a particular hierarchy of inclusions and the state function reduction allows any finite sequence of inclusions. The negentropy gain would correspond to the total negentropy gain associated with the inclusion sequences obtained as sum of $S = -log(\prod_i d_i) =$

$-\sum_i log(d_i)$. The larger the number of inclusions in the sequence, the larger the information gain. This makes sense since the measurement resolution would increase. The longer the sequence of inclusions, the higher the negentropy gain. This picture is different from that resulting from NE: in this case reduction to lower dimensional space tends to give smaller negentropy gain.

The topology of the many-sheeted space-time encourages the generalization of the notion of quantum entanglement in such a manner that unentangled systems can possess entangled subsystems. One can say that the entanglement between sub-selves is not visible in the resolution characterizing selves. This makes possible sharing and fusion of mental images central for TGD inspired theory of consciousness. These concepts find a deeper justification from the quantum measurement theory for hyper-finite factors of type II_1 for which the finite measurement resolution is basic notion.

4 Some Consequences Of NMP

In the sequel the most obvious consequences of self measurement and NMP are discussed from the point of view of physics, biology, cognition, and quantum computing. The recent discussion differs considerably from the earlier one since several new elements are involved. ZEO and the hierarchy of CDs, the hierarchy of Planck constants and dark matter, and - perhaps most importantly - the better understanding NE as something genuinely new and making sense in the intersection of real and various p-adic worlds at which living matter is assumed to reside.

4.1 NMP And P-Adic Length Scale Hypothesis

The original form of the p-adic length scale hypothesis stated that physically most interesting p-adic primes satisfy $p \simeq 2^k$, k prime or power of prime. It has however turned out that all positive integers k are possible. Surprisingly few new length scales are predicted by this generalization in physically interesting length scales. p-Adic length scale hypothesis leads to excellent predictions for elementary particle masses (note that the mass prediction is exponentially sensitive to the value of k) and explains also some interesting length scales of biology: for instance, the thicknesses of the cell membrane and of single lipid layer of cell membrane correspond to $k = 151$ and $k = 149$ respectively.

4.1.1 Various explanations for the origin of p-adic length scale hypothesis

The big problem of p-adic TGD is to derive this hypothesis from the basic structure of the theory.

1. One argument is based on black hole-elementary particle analogy [K18] leading to the generalization of the Hawking-Bekenstein formula: the requirement leading to the p-adic length scale hypothesis is that the radius of the so called elementary particle horizon is itself a p-adic length scale. This argument involves p-adic entropy essentially and it seems that information processing is somehow involved.

2. Zero energy ontology predicts p-adic length scale hypothesis if one accepts the assumption that the proper time distances between the tips of CDs come as powers of 2 [K18]. A more general highly suggestive proposal is that the relative position between tips forms a lattice at proper time constant hyperboloid having as a symmetry group discrete subgroup of Lorentz group (which could reduce to a subgroup of the group $SO(3)$ acting as isotropy group for the time-like direction defined by the relative coordinate between the tips of CD [K23].

   p-Adic length scale hypothesis could be understood as a resonance in frequency domain -most naturally for massless particles like photons. The secondary p-adic time scale for favored p-adic primes must be as near as possible to the proper time distance between the tips of CD. Mersenne primes $M_n = 2^n - 1$ (n is prime) satisfy this condition. Also $log(p)$ is in this case as near as possible to $log(2^n)$ and in the sense that the unit of negentropy defined as $log(2^n - m(n))/log(2^n)$ is maximized. This argument might work also for Gaussian Mersennes $G_n = (1+i)^n - 1$ (n is prime also now) if one restricts the consideration to Gaussian primes.

A more general and more realistic looking hypothesis is that a given CD can have partonic light-like 3-surfaces ending at its boundaries for all p-adic length scales up to that associated with CD: powers of 2 would be favored by the condition of commeasurability very much analogous to frequency doubling.

3. An exciting possibility, suggested already earlier half seriously, is that evolution is present already at elementary particle level. This is the case if elementary particles reside in the intersection of real and p-adic worlds. The success of p-adic mass calculations and the identification of p-adic physics as physics of cognition indeed forces this interpretation. In particular, one can understand p-adic length scale hypothesis as reflecting the survival of the cognitively fittest p-adic topologies.

I have discussed also other explanations.

1. A possible physical reason for the primes near prime powers of 2 is that survival necessitates the ability to co-operate, to act in resonance: this requirement might force commeasurability of the length scales for p-adic space-time sheet (p_1) glued to larger space-time sheet ($p_2 > p_1$). The hierarchy would state from 2-adic level having characteristic fractal length scales coming as powers of $\sqrt{2}$. When $p > 2$ space-time sheet is generated during cosmological evolution $L(p)$ for it must correspond to power of $\sqrt{2}$ so that one must have $p \simeq 2^n$.

2. A model for learning [K3] as a transformation of the reflective level of consciousness to proto level supports the view that evolution and learning occur already at elementary particle level as indeed suggested by NMP: the p-adic primes near power of prime powers of two are the fittest ones. The core of the argument is the characterization of learning as a map from 2^N many-fermion states to M association sequences. The number of association sequences should be as near as possible equal to 2^N. If M is power of prime: $M = p^K$, association sequences can be given formally the structure of a finite field $G(p, K)$ and p-adic length scale hypothesis follows as a consequence of $K = 1$. NMP provides the reason for why $M = p^K$ is favored: in this case one can construct realization of quantum computer with entanglement probabilities $p_k = 1/M = 1/p^K$ and the negentropy gain in quantum jump is $Klog(p)$ while for M not divisible by p the negentropy gain is zero.

4.1.2 Generalization of p-adic length scale hypothesis suggested by NMP

The assumption that adelic physics has as its number theoretically universal core the physics for algebraic extensions of rationals inducing those of p-adic numbers fields allows to understand preferred p-adic primes as those which are ramified [K36]. Ramified prime decomposes into a product of primes involving higher powers of prime of the extension and maximally ramified primes correspond to irreducible extensions satisfying so called Eisenstein criterion.

In strong form of holography p-adic continuations of 2-surfaces to preferred extrmals identifiable as imaginations would be easy due to the existence of p-adic pseudo-constants. The continuation could fail for most configurations of partonic 2-surfaces and string world sheets in the real sector: the interpretation would be that some space-time surfaces can be imagined but not realized [K17]. For certain extensions the number of realizable imaginations could be exceptionally large. These extensions would be winners in the number theoretic fight for survival and and corresponding ramified primes would be preferred p-adic primes. This does not yet explain p-adic length scale hypothesis [K18, K15] stating that p-adic primes near powers of 2 are favored.

A possible generalization of this hypothesis is that primes near powers of prime are favored. There indeed exists evidence for the realization of 3-adic time scale hierarchies in living matter [I1] (`http://byebyedarwin.blogspot.fi/p/english-version_01.html`) and in music both 2-adicity and 3-adicity could be present, this is discussed in TGD inspired theory of music harmony and genetic code [K20].

The weak form of NMP might come in rescue here.

1. Entanglement negentropy for a NE [K16] characterized by n-dimensional projection operator is the $log(N_p(n)$ for some p whose power divides n. The maximum negentropy is obtained if the power of p is the largest power of prime divisor of p, and this can be taken as definition of

number theoretic entanglement negentropy. If the largest divisor is p^k, one has $N = k \times log(p)$. The entanglement negentropy per entangled state is $N/n = klog(p)/n$ and is maximal for $n = p^k$. Hence powers of prime are favoured which means that p-adic length scale hierarchies with scales coming as powers of p are negentropically favored and should be generated by NMP. Note that $n = p^k$ would define a hierarchy of $h_{eff}/h = p^k$. During the first years of h_{eff} hypothesis I believe that the preferred values obey $h_{eff} = r^k$, r integer not far from $r = 2^{11}$. It seems that this belief was not totally wrong.

2. If one accepts this argument, the remaining challenge is to explain why primes near powers of two (or more generally p) are favoured. $n = 2^k$ gives large entanglement negentropy for the final state. Why primes $p = n_2 = 2^k - r$ would be favored? The reason could be following. $n = 2^k$ corresponds to $p = 2$, which corresponds to the lowest level in p-adic evolution since it is the simplest p-adic topology and farthest from the real topology and therefore gives the poorest cognitive representation of real preferred extremal as p-adic preferred extermal (Note that $p = 1$ makes formally sense but for it the topology is discrete).

3. Weak form of NMP [K16, K26] suggests a more convincing explanation. The density matrix of the state to be reduced is a direct sum over contributions proportional to projection operators. Suppose that the projection operator with largest dimension has dimension n. Strong form of NMP would say that final state is characterized by n-dimensional projection operator. Weak form of NMP allows free will so that all dimensions $n - k$, $k = 0, 1, ...n - 1$ for final state projection operator are possible. 1-dimensional case corresponds to vanishing entanglement negentropy and ordinary state function reduction isolating the measured system from external world.

4. The negentropy of the final state per state depends on the value of k. It is maximal if $n - k$ is power of prime. For $n = 2^k = M_k + 1$, where M_k is Mersenne prime $n - 1$ gives the maximum negentropy and also maximal p-adic prime available so that this reduction is favoured by NMP. Mersenne primes would be indeed special. Also the primes $n = 2^k - r$ near 2^k produce large entanglement negentropy and would be favored by NMP.

5. This argument suggests a generalization of p-adic length scale hypothesis so that $p = 2$ can be replaced by any prime.

This argument together with the hypothesis that preferred prime is ramified would correlate the character of the irreducible extension and character of super-conformal symmetry breaking. The integer n characterizing super-symplectic conformal sub-algebra acting as gauge algebra would depends on the irreducible algebraic extension of rational involved so that the hierarchy of quantum criticalities would have number theoretical characterization. Ramified primes could appear as divisors of n and n would be essentially a characteristic of ramification known as discriminant. An interesting question is whether only the ramified primes allow the continuation of string world sheet and partonic 2-surface to a 4-D space-time surface. If this is the case, the assumptions behind p-adic mass calculations would have full first principle justification.

4.2 NMP And Thermodynamics

The physical status of the second law has been a longstanding open issue in physics- in particular biophysics. In positive energy ontology the understanding of the origin of second law is simple. Quantum jumps involve state function reduction (or more generally, self measurement) with a random outcome and in the case of ensemble of identical system this leads to to a probability distribution for the states of the members of the ensemble. This implies Boltzmann equations implying the second law. In TGD framework there are many elements which force to question this simple picture: zero energy ontology and CDs, effective four-dimensionality of the ensemble defined by states assignable to sub-CDs, hierarchy of Planck constants, and the possibility of negentropic entanglement.

4.2.1 Zero energy ontology and thermodynamical ensembles

Zero energy ontology means that the thermodynamics appears both at the level of quantum states and at the level of ensembles. At the level of quantum states this means that M-matrix can be seen

as a complex square root of the density matrix: $\rho = MM^\dagger$, where M is expressible as a product of a positive and diagonal square root of density matrix and unitary S-matrix identifiable as the S-matrix used in quantum physics. U matrix can be seen as a collection of M-matrices as will be found later so that U-matrix fixes M-matrices contrary to what was believed originally. One can say that thermodynamics -at least in some sense- is represented at the level of single particle states. It is natural to assume that this density matrix is measured in particle physics experiment, and that this measurement corresponds to a state function reduction, which in standard physics picture corresponds to a preparation for the initial states and state function reduction for the final states.

The p-adic thermodynamics, which applies to conformal weights rather than energy, predicts successfully elementary particle masses [K33] and should reduce to this thermodynamics. That p-adic thermodynamics can be applied at all conforms with the view that even elementary particles (that is fermions serving as their basic building bricks) reside in the intersection of the real and p-adic worlds so that either p-adic thermodynamics or real thermodynamics with additional constraints on temperature implied by number theory applies.

M-matrix corresponds to a square root of density matrix, which suggests that also ordinary thermodynamics should be replaced with its square root bringing in phase factors. The imaginary part appearing in the exponent of the vacuum functional defined by Kähler action in Minkowskian regions could have interpretation in terms of a square root of thermodynamics. I have proposed this kind of description as a generalization of the model of cell membrane based on generalization of Josephson junction by bringing in dark currents flowing along magnetic flux tubes [K6].

4.2.2 Thermodynamical ensembles are 4-dimensional

The hierarchy of CDs within CDs defines a hierarchy of sub-systems and sub-CDs define in a natural manner 4-dimensional ensemble. If the state function reduction leads to unentangled states, the outcome is an ensemble describable by the density matrix assignable to the single particle states. The sequence of quantum jumps is expected to lead to a 4-D counterpart of thermodynamical ensemble and thermodynamics results when one labels the states by the quantum numbers assignable to their positive energy part. Entropy is assigned with entire 4-D CD rather than to its 3-dimensional time=constant snapshots. The thermodynamical time is basically the subjective time and measured in terms of quantum jumps but has a correlation with geometric time as explained in [K1] and explained briefly below.

This picture differs from the standard views, and this might explain the paradoxical situation in cosmology resulting from the fact that the initial state of the universe in the standard sense of the word looks highly entropic whereas second law would suggest the opposite [K23]. The cosmological entropy is assigned with a CD of size scale defined by the value of the age of the universe. In this kind of situation each quantum jump replaces the zero energy state with a new one and also induces a drift in the space of CDs to the direction of larger CDs with size defined by the proper time distance between the tips of CD coming as power of 2. Entropy as a function of cosmic time corresponds in TGD framework to the increase of the 4-D entropy as a function of the quantized proper time distance between the tips of the CD.

In this framework it is possible to understand second law in cosmic time scales apart from the possible effects related to NE responsible for the evolution and breaking of second law in arbitrarily long time scales caused by the transformation of thermal ensembles to quantum coherent dark matter. For instance, the number of sub-CDs increases meaning the increase of the size of the ensemble and the emergence of new p-adic length scales as the size of cosmic CD increases. What is fascinating is that the TGD counterpart of cosmic time is quantized in powers of two. This might have predictable effects such as the occurrence of the cosmic expansion in a jump-wise manner. I have discussed an explanation of the accelerated cosmic expansion in terms of quantum jumps of this kind but starting from somewhat different picture [K23].

4.2.3 Does NMP replace second law?

In TGD NMP defines the fundamental law of evolution. If the maximal negentropy gain corresponds to n-dimensional projector and all outcomes for $m \leq n$ are equally probable (weak NMP) the average value of the dimension associated with the projector of the reduced sub-space is $n/2$.

The average negentropy gain is average over the various values of m and has sensitive dependence on the prime number decomposition of m. If m is power of prime, the negentropy gain is large. Therefore the weak form of NMP makes it possible to have larger negentropy gain for $m < n$ than for n having factors if m is prime or has small number of factors.

Second law reflecting the non-determinism of state function reduction is expected to hold true when the reduction takes place to 1-D sub-space - dark matter is not generated in state function reductions. The process can have stages involving dark matter phases labelled by non-standard value of Planck constant but the system returns back to the state in which it consists of visible matter.

The generation of NE indeed breaks second law. Particles are not anymore independent members of a thermodynamical ensemble but form larger units. Since the number of particles is reduced also thermodynamical entropy is reduced and second law can be broken in the geometric time scale considered.

4.2.4 How second law must be modified?

Even in this case second law as such does not certainly apply in TGD framework without special restrictions. Many of these special prerequisites hold true also in the case of NMP.

1. The hierarchy of CDs forces to introduce a fractal version of the second law taking into account the p-adic length scale hypothesis and dark matter hierarchy. This means that the idea about quantum parallel Universes generalizes to that of quantum parallel dissipating Universes. For instance, the parton model of hadrons based on quarks and gluons relies on kinetic equations and is basically thermodynamical whereas the model for hadron applied at low energies is quantum mechanical. These two views are consistent if quantum parallel dissipation realized in terms of a hierarchy of CDs is accepted. p-Adic length scale hierarchy with p-adic length scale hypothesis stating that primes near powers of two are preferred corresponds to this dissipative quantum parallellism. Dark matter hierarchy brings in a further dissipative quantum parallelism.

2. Second law should always be applied only at a given level of p-adic and dark matter hierarchy and one must always take into account two time scales involved corresponding to the time scale assignable to the system identifiable as the time scale characterizing corresponding CD and the time scale in which the system is observed. Only if the latter time scale is considerably longer than the CD time scale, second law is expected to make sense in TGD framework - this provided one restricts the consideration to the entropic entanglement. The reason is that the Boltzmann equations implying the second law require that the geometric time scale assignable to quantum jump is considerably shorter than the time scale of observation: this guarantees that the random nature of quantum jump allows to use statistical approach.

3. The reduction of entanglement entropy at single particle level implies the increase of thermodynamical entropy at the level of ensemble in the case of entropic non-binding entanglement. This applies to bound state entanglement leading to a generation of entropy at the level of binding systems and a reduction of the contribution of the bound systems to the entropy of the entire system. Note however the emission of binding energy -say in form of photons- could take care of the compensation so that entropy would be never reduced for ensemble. For NE the situation is different.

4. One must be careful in distinguishing between geometric and subjective time. In the case of subjective time the negentropy increases in statistical sense forever unless the CD disappears in some quantum jump (highly non-probable for large enough CDs). If not, then endless evolution at the level of conscious experience is possible in the intersection of real and p-adic worlds and heat death is not the fate of the Universe as in ordinary thermodynamics.

   The arrow of geometric time changes in the state function reduction to the opposite boundary (act of free will of self leading to a death of sub-self) and negentropy increases. This implies that entropy increases in opposite time direction and behaves like syntropy.

5. In thermodynamics the breaking of second law must correspond to the breaking of ergodicity. Spin glasses are non-ergodic systems and TGD Universe is analogous to a 4-D quantum spin

glass by the failure of strict non-determinism of Kähler action reflecting itself as vacuum degeneracy. Does the quantum spin glass property of the TGD universe imply the breaking of the second law? Gravitation has been seen as one possible candidate for the breaking second law because of its long range nature. It is indeed classical gravitational energy which distinguishes between almost degenerate spin glass states. The huge value of gravitational Planck constant associated with space-time sheets mediating gravitational interaction and making possible perturbative quantum treatment of gravitational interaction would indeed suggest the breaking of second law in cosmological time scales. For instance, black hole entropy which is inversely proportional to $GM^2/\hbar_{gr}$ would be for the values of gravitational Planck constant involved of the order of unity.

This breaking of ergodicity implied by 4-D spin glass character of TGD might have an interpretation in terms of NE. The non-determinism implying the ergodicity is behind the hierarchy of quantum criticalities in turn realizing NE.

4.2.5 What do experiments say about second law?

That the status of the second law is far from settled is demonstrated by an experiment performed by a research group in Australian National University [D1]. The group studied a system consisting of 100 small beads in water. One bead was shot by a laser beam so that it became charged and was trapped. The container holding the beads was then moved from side to side 1000 times per second so that the trapped bead dragged first one way and then another. The system was monitored and for monitoring times not longer than.1 seconds second law did not hold always: entropy could also decrease.

1. What is remarkable that .1 seconds defines the duration τ of the memetic code word and corresponds to the secondary p-adic time scale $T_p(2) = \sqrt{p}L_p/c$ associated with Mersenne prime $p = M_{127}$ characterizing electron. This correspondence follows solely from the model of genetic code predicting hierarchy of codes associated with $p = 3, 7, 127$ (genetic code), $p = M_{127}$, ... τ should be the fundamental time scale of consciousness. For instance, average alpha frequency 10 Hz corresponds to this time scale and "features" inside cortex representing sensory percepts have average duration of .1 seconds.

   For electrons the CDs would have spatial size $L = 3 \times 10^7$ meters, which is slightly smaller than the circumference of Earth ($L = cT$, $T = .1$ s, the duration of sensory moment) so that they would have a strong overlap. One can of course ask whether this is an accident. For instance, the lowest Schumann frequency is around 7.8 Hz and not far from 10 Hz. What is interesting that Bohr orbit model [K22] predicts that Universe might be populated by Earth like systems having same distance from their Sun (stars with mass near that of Sun are very frequent). Bohr orbitology applied to Earth itself could also lead to the quantization of the radius of Earth.

2. The first observation was made for more than 15 years ago. Even more remarkable is the recent observation that the time scale of CD associated with electron is.1 seconds. Can one assign the breaking of the second law with the field bodies of electrons?

3. The experiment involves also a millisecond time scale. I do not know whether it is essential that the time scale is just this but one can play with the though that it is. Millisecond time scale is roughly the duration of seventh bit of the genetic codeword if its bits correspond to CDs with sizes coming as subsequent octaves of the basic time scale. Millisecond defines also the time scale for the duration of the nerve pulse and the frequency of kHz cortical synchrony.

   At the level of CDs millisecond time scale would correspond to a secondary p-adic time scale assignable to $k = 120$. Only u and d quarks, which appear with several p-adic mass scales in hadron physics and are predicted to be present as light variants also in nuclear physics as predicted by TGD, could correspond to this p-adic length scale: the prediction for their mass scale would be 5 MeV. Does this mean that the basic time scales of living matter correspond directly to the basic time scales of elementary particle physics?

4. A further interesting point is that neutrinos correspond to.1 eV mass scale. This means that the p-adic length scale is around $k = 167$ which means that the corresponding CD

has time scale which is roughly 2^{40} times that for electron and corresponds to the primary p-adic length scale of 2.5 μm (size of cellular nucleus) and tothe time scale of 10^4 years. I have proposed that so called cognitive neutrino pairs consisting of neutrino and antineutrino assignable to the opposite throats of wormhole contact could play key a role in the formation of cognitive representations [K20]. This assumption looks now un-necessarily restrictive but one could quite well consider the possibility that neutrinos are responsible for the longest time scales assignable to consciousness for ordinary value of $\hbar$ (not necessarily our consciousness!). Large value of $\hbar$ could make also possible the situation in which intermediate gauge bosons are effectively massless in cell length scale so that electro-weak symmetry breaking would be absent. This would require $\hbar \simeq 2^{33}$. For this value of $\hbar$ the time scale of electronic CD is of the order of the duration of human of human life cycle. This would scale up the Compton length of neutrino to about 10 kilometers and the temporal size of neutrino CD to a super-cosmological time scale.

4.3 NMP And Biology

The notion of self is crucial for the understanding of bio-systems and consciousness. It seems that the NE is the decisive element of life and that one can say that in metaphorical sense life resides in the intersection of real and p-adic worlds.

4.3.1 Life as islands of rational/algebraic numbers in the seas of real and p-adic continua?

NMP and negentropic entanglement demanding entanglement probabilities which are equal to inverse of integer, is the starting point. Rational and even algebraic entanglement coefficients make sense in the intersection of real and p-adic words, which suggests that in some sense life and conscious intelligence reside in the intersection of the real and p-adic worlds.

What could be this intersection of realities and p-adicities?

1. The facts that fermionic oscillator operators are correlates for Boolean cognition and that induced spinor fields are restricted to string world sheets and partonic 2-surfaces suggests that the intersection consists of these 2-surfaces.

2. Strong form of holography allows a rather elegant adelization of TGD by a construction of space-time surfaces by algebraic continuations of these 2-surfaces defined by parameters in algebraic extension of rationals inducing that for various p-adic number fields to real or p-adic number fields. Scattering amplitudes could be defined also by a similar algebraic contination. By conformal invariance the conformal moduli characterizing the 2-surfaces would defined the parameters.

This suggests a rather concrete view about the fundamental quantum correlates of life and intelligence.

1. For the minimal option life would be effectively 2-dimensional phenomenon and essentially a boundary phenomenon as also number theoretical criticality suggests. There are good reasons to expect that only the data from the intersection of real and p-adic string world sheets partonic two-surfaces appears in U-matrix so that the data localizable to strings connecting partonic 2-surfaces would dictate the scattering amplitudes.

A good guess is that algebraic entanglement is essential for quantum computation, which therefore might correspond to a conscious process. Hence cognition could be seen as a quantum computation like process, a more appropriate term being quantum problem solving [K7]. Living-dead dichotomy could correspond to rational-irrational or to algebraic-transcendental dichotomy: this at least when life is interpreted as intelligent life. Life would in a well defined sense correspond to islands of rationality/algebraicity in the seas of real and p-adic continua. Life as a critical phenomenon in the number theoretical sense would be one aspect of quantum criticality of TGD Universe besides the criticality of the space-time dynamics and the criticality with respect to phase transitions changing the value of Planck constant and other more familiar criticalities. How closely these criticalities relate remains an open question [K21].

The view about the crucial role of rational and algebraic numbers as far as intelligent life is considered, could have been guessed on very general grounds from the analogy with the orbits of a dynamical system. Rational numbers allow a predictable periodic decimal/pinary expansion and are analogous to one-dimensional periodic orbits. Algebraic numbers are related to rationals by a finite number of algebraic operations and are intermediate between periodic and chaotic orbits allowing an interpretation as an element in an algebraic extension of any p-adic number field. The projections of the orbit to various coordinate directions of the algebraic extension represent now periodic orbits. The decimal/pinary expansions of transcendentals are un-predictable being analogous to chaotic orbits. The special role of rational and algebraic numbers was realized already by Pythagoras, and the fact that the ratios for the frequencies of the musical scale are rationals supports the special nature of rational and algebraic numbers. The special nature of the Golden Mean, which involves $\sqrt{5}$, conforms the view that algebraic numbers rather than only rationals are essential for life.

Later progress in understanding of quantum TGD allows to refine and simplify this view dramatically. The idea about p-adic-to-real transition for space-time sheets as a correlate for the transformation of intention to action has turned out to be un-necessary and also hard to realize mathematically. In adelic vision real and p-adic numbers are aspects of existence in all length scales and mean that cognition is present at all levels rather than emerging. Intentions have interpretation in terms of state function reductions in ZEO and there is no need to identify p-adic space-time sheets as their correlates.

That only algebraic extensions are possible is of course only a working hypothesis. Also finite-dimensional extensions of p-adic numbers involving transcendentals are possible and might in fact be necessary. Consider for instance the extension containing $e, e^2, .., e^{p-1}$ as units (e^p is ordinary p-adic number. Infinite number of analogous finite-dimensional extensions can be constructed by taking a function of integer variable such that $f(p)$ exists both p-adically and as a real transcendental number. The powers of $f(p)^{1/n}$ for a fixed value of n define a finite-dimensional transcendental extension of p-adic numbers if the roots do not exist p-adically.

Numbers like $log(p)$ and π cannot belong to a finite-dimensional extension of p-adic numbers [K11]. One cannot of course take any strong attitude concerning the possibility of infinite-dimensional extensions of p-adic numbers but the working hypothesis has been that they are absent. The phases $exp(i2\pi/n)$ define finite dimensional extensions allowing to replace the notion of angle in finite measurement resolution with the corresponding phase factors in finite measurement. The functions $exp(i2\pi q/n)$, where q is arbitrary p-adic integers define in a natural manner the physical counterparts of plane waves and angular momentum eigenstates not allowing an identification as ordinary p-adic exponential functions. They are clearly strictly periodic functions of q with a finite value set. If n is divisible by a power of p, these functions are continuous since the values of the function for q and $q + kp^n$ are identical for large enough values of n. This condition is essential and means in the case of plane waves that the size scale of a system (say one-dimensional box) is multiple of a power of p.

4.3.2 NMP and self-organization

NMP leads to new vision about self-organization about which adetailed vision is discussed in [K21]. Here only some key points are emphasized.

1. Dissipation selects the asymptotic self-organization patterns in the standard theory of self-organization and the outcomes are interesting in the presence of energy feed. The feed of energy can be generalized to feed of any kind of quantum numbers: for instance, feed of quantum numbers characterizing qualia. In fact, energy increment in quantum jump defines one particular kind of quale [K12]. Similar picture should apply now.

2. The fundamentally new element is that in ZEO basic objects are pairs of 3-D surfaces at the opposite boundaries of CDs. By holography the basic geometric objects are 4-dimensional or equivalently 3-dimensional. Strong form of holography allows also to identify the objects carrying information about quantum states as string world sheets and partonic 2-surfaces at the boundaries of CD. Self-organization leads to an asymptotic spatio-temporal pattern rather than spatial pattern, behavior or function. This picture is especially useful when one

tries to understand morphogenesis and the emergence of functions and behaviors in biology and neuroscience [K32].

3. The notion of self relates very closely to self-organization in TGD framework [K21]. Self assignable to CD is a dissipative structure because it has sub-selves which dissipate quantum parallelly with it. Self as a perceiver maps the dissipation at the level of quantities in the external world to dissipation at the level of qualia in the internal world.

4. Dissipation leads to self-organization patterns and in the absence of external energy feed to thermal equilibrium. Thus thermodynamics emerges as a description for an ensemble of selves or for the time average behavior or single self when external energy feed to system is absent. One can also understand how the dissipative universe characterized by the presence of parameters like diffusion constants, conductivities, viscosities, etc.. in the otherwise reversible equations of motion, emerges. Dissipative dynamics is in a well defined sense the envelope for the sequence of reversible dynamical evolutions modelling the sequence of final state quantum histories defined by quantum jumps.

5. Quantum self-organization can be seen as iteration of the unitary process followed by state function reduction and leads to fixed point self-organization patterns analogous to the patterns emerging in Benard flow. Since selves approach "asymptotic selves", dissipation can be regarded as a Darwinian selector of both genes and memes. Thus not only surviving physical systems but also stable conscious experiences of selves, habits, skills, behaviors, etc... are a result of Darwinian selection.

6. In TGD one must distinguish between two kinds of self organizations corresponding to the entropic bound state entanglement and NE. Biological self-organization could be therefore fundamentally different from the non-biological one. The success of the p-adic mass calculations suggest that elementary particles reside in the intersection of real and p-adic worlds so that one should be very cautious in making strong conclusions. Certainly the intentional, goal-directed behavior of the system in some time scale is a signature of negentropic self-organization but it is difficult to apply this criterion in time scales vastly different from human time scales. It is the field bodies (or magnetic bodies), which can be assigned naturally to CDs which suggests that the negentropic self organization occurs at this level. TGD based vision about living matter actually assumes this implicitly.

7. What is new that even quantum jump itself can be seen as a self-organization process analogous to Darwinian selection, which yields a state containing only bound state state entanglement or NE and representing analog of the self-organization patterns. By macro-temporal quantum coherence effectively gluing quantum jumps sequences to single quantum jump this pattern replicates itself fractally in various time scales. Thus self-organization patterns can be identified as bound states and states paired by a NE and the development of the self-organization pattern as a fractally scaled up version of single quantum jump. Second new element is that dissipation is not mere destruction of order but producer of jewels. A further new element is that dissipation can occur in quantum parallel manner in various scales.

8. The failure of the determinism in standard sense for Kähler action is consistent with the classical description of dissipation. In particular, the emergence of sub-selves inside self looks like dissipation from outside but corresponds to self-organization from the point of view of self. 4-dimensional spin glass degeneracy meaning breaking of ergodicity crucial for self-organization is highly suggestive on basis of the vacuum degeneracy of Kähler action, and this alone predicts ultra-metric topology for the landscape of the maxima of Kähler function defined in terms of Kähler action so that p-adicity emerges naturally also in this manner.

One particularly interesting concrete prediction is that the time scales assignable to CDs come as powers of two. This predicts fundamental frequencies coming as powers of two, and the hierarchy of Planck constants predicts rational or at least integer multiples of these frequencies. Could these powers of two relate to frequency doubling rather generally observed in hydrodynamical self-organizing systems?

4.3.3 Evolution and NMP

Evolution has many facets in TGD framework.

1. A key aspect of evolution relates to the hierarchy of Planck constants labelling a hierarchy of quantum criticalities. The phase transitions reducing criticality, increasing Planck constant, and generatic NE occur spontaneously so that evolution is unavoidable. This is in sharp conflict with the standard belief that life is a thermodynamical fluctuation.

2. In the adelic vision evolution reduce to the increase of the complexity of the algebraic extension of rationals defining the preferred primes which are primes near powers of prime by NMP. The value of n characterizing Planck constant would correspond to the product of ramified primes for a given extension. Infinite primes representing bound states in arithmetic quantum field theory could code for the irreducible polynomials characterizing the basic algebraic extension whose maximal Abelian extension is represented in terms of adeles [K36].

3. A further natural characterization of evolution is in terms of p-adic topology relating naturally to cognition. p-Adic primes near powers of two are favored if CDs have the proposed discrete size spectrum. From the point of view of self this would be essentially cosmic expansion in discrete jumps. CDs and can be characterized by powers of 2 and if partonic 2-surfaces correspond to effective p-adic p-adic topology characterized by a power of two, one obtains the commeasurability of the secondary p-adic time scale of particle and that of CD in good approximation.

4. The notion of infinite primes motivates the hypothesis that the many-sheeted structure of space-time can be coded by infinite primes [K24]. The number of primes larger than given infinite prime P is infinitely larger than the number of primes than P. The infinite prime P characterizing the entire universe decomposes in a well defined manner to finite primes and p-adic evolution at the level of entire universe is implied by local p-adic evolution at the level of selves. Therefore maximum entanglement negentropy gain for p-adic self increases at least as $log(p)$ with p in the long run. This kind of relationship might hold true for real selves of p-adic physics is physics of cognitive representations of real physics as suggested by the success of p-adic mass calculations. Thus it should be possible to assign definite p-adic prime to each partonic 2-surface.

Just for fun one can play also with numbers.

1. The highest dark matter level associated with self corresponds to its geometric duration which can be arbitrarily long: the typical duration of the memory span gives an idea about the level of dark matter hierarchy involved if one assumes that the time scale.1 seconds assignable to electrons is the fundamental time scale. If the time scale T of human life cycle corresponds to a secondary p-adic time scale then $T = 100$ years gives the rough estimate $r \equiv \hbar/\hbar_0 = 2^{33}$ if this time scale corresponds to that for dark electron. The corresponding primary p-adic time length scale corresponds to $k = 160$ and is 2.2×10^{-7} meters.

2. If human time scale -taken to be $T = 100$ years- corresponds to primary p-adic time scale of electron, one must have roughly $r = 2^{97}$.

I have already discussed the second law in TGD framework and it seems that its applies only when the time scale of perception is longer than the time scale characterizing the level of the p-adic and dark matter hierarchy. Second law as it is usually stated can be seen as an unavoidable implication of the materialistic ontology.

4.3.4 Stable entanglement and quantum metabolism as different sides of the same coin

The notion of binding has two meanings. Binding as a formation of bound state and binding as a fusion of mental images to larger ones essential for the functioning of brain and regarded as one the big problems of consciousness theory.

Only bound state entanglement and NE are stable against the state reduction process. Hence the fusion of the mental images implies the formation of a bound entropic state- in this case the two interpretations of binding are equivalent- or a negentropic state, which need not be bound state.

1. In the case of NE bound state need not be formed and the interesting possibility is that the NE could give rise to stable states without binding energy. This could allow to understand the mysterious high energy phosphate bond to which metabolic energy is assigned in ATP molecule containing three phosphates and liberated as ATP decays to ADP and phosphate molecule. Negentropic entanglement could also explain the stability of DNA and other highly charged biopolymers. In this framework the liberation of metabolic (negentropic) energy would involve dropping of electrons to a larger space-time sheets accompanying the process $ATP \to ADP + P_i$. A detailed model of this process is discussed in [K10].

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

2. The formation of bound state entanglement is expected to involve a liberation of the binding energy and this energy might be a usable energy. This process could perhaps be coined as quantum metabolism and one could say that quantum metabolism and formation of bound states are different sides of the same coin. It is known that an intense neural activity, although it is accompanied by an enhanced blood flow to the region surrounding the neural activity, does not involve an enhanced oxidative metabolism [J5] (that is $ATP \to ADP$ process and its reversal). A possible explanation is that quantum metabolism accompanying the binding is involved. Note that the bound state is sooner or later destroyed by the thermal noise so that this mechanism would in a rather clever manner utilize thermal energy by applying what might be called buy now–pay later principle.

If these interpretations are correct, there would be two modes of metabolism corresponding to two different kinds of fusion of mental images.

4.4 NMP, Consciousness, And Cognition

As already found NMP dictates the subjective time development of self and is therefore the basic law of consciousness. If p-adic physics is the physics of cognition, the most exotic implications of NMP relate to cognition rather than standard physics.

4.4.1 Thermodynamics for qualia

Concerning qualia one can consider two views.

1. If only entropic entanglement is assumed, second law would hold true also at the level of conscious experience of self, which can be seen as an ensemble of its sub-selves assignable to sub-CDs. The randomness of the state function reduction process implies that conscious experience involves statistical aspects in the sense that the experienced qualia correspond to the averages of quantum number and zero mode increments over the sub-selves assignable to sub-CDs. When the number of quantum jumps in the ensemble defining self increases, qualia get more entropic and fuzzy unless macro-temporal quantum coherence changes the situation.

2. ZEO and NE means departure from this picture if sub-CDs can generate NE. This is expected to be true if they overlap if one believes on standard argument for the formation of macroscopic quantum phases. In this case the flux tubes connecting space-time sheets assignable to the sub-CDs would serve as a space-time correlate for the NE.

The basic questions are whether sensory qualia can really correspond to the increments of quantum numbers in quantum jump and whether these quantum jumps are assignable to entropic or negentropic qualia. What is clear that the sensory qualia such as colors are assigned to an object of external world rather predictably. This is not obvious if this process is based on quantum jump.

1. The original view inspired by standard view about state function reduction (positive energy ontology) was that qualia are determined basically as increments of quantum numbers [K12]. In ordinary statistical physics measured quantities would correspond to quantum numbers basically. The basic function of sensory organs would be to map quantum numbers to quantum number increments so that our sensory perception is in reasonable approximation about world rather than changes of the world.

2. Entropic entanglement is reduced to zero in state function reduction for individual sensory receptor and the outcome involves all possible values of quale, say different fundamental colors for which I have proposed a model in terms of QCD color [K12]. If the probability of particular value of quale is much larger than others, one can have statistical ensemble giving rise to predictable quale as ensemble average.

What happens when ZEO based view about state function reduction is adopted?

1. Now sensory mental image corresponds to a sub-self, which in turn corresponds to a repeated state function reduction to a fixed (passive) boundary of sub-CD. Does sub-self without any sub-sub-selves correspond to conscious experience about quantum numbers instead of only change of quantum numbers? One cannot exclude this possibility. For instance, three colored states for quarks would correspond to three fundamental colors for this option.

   The alternative possibility is that quantum jumps of sub-selves give rise to the sensory mental images and the increments of quantum numbers define the qualia. Sub-selves without sub-selves would not give rise to sensory qualia. That consciousness involves always change could be seen as a support for this interpretation but one can ask what change is. Does change mean state function reduction in standard sense or does it mean a sequence of repeated state function reductions leaving the passive boundary of CD invariant but inducing sensation about flow of time and sensory experience?

2. In ZEO the increments must correspond to increments of quantum numbers for (say) positive energy part of the state. A sensation of (say) given color requires a continual feed of corresponding quantum number increment to the positive energy part of the system. Some kind of far from equilibrium thermodynamics seems to be necessary with external feed of quantum numbers generalizing the external feed of energy. The capacitor model of a sensory receptor [K12] realizes this idea in terms of generalized di-electric breakdown implying opposite charging of the capacitor plates in question. Note that in ZEO also the positive and negative energy parts of the zero energy state assignable to capacitor plates would be also analogous to a pair of oppositely charged capacitor plates and one can speak about capacitor also in time direction.

3. The flow of quantum numbers can be interpreted also in terms of feed of NE to the sub-CD of sub-self allowing it to satisfy the needs of NMP and avoid the lethal first state function reduction to the opposite boundary of its sub-CD. NE feed would accompany the feed of quantum numbers and would be accompanied by feed of metabolic energy and/or some other metabolite. Energy metabolism is indeed only one particular variant of metabolism. Metabolism would be always basically feed of NE assignable to system with quantum numbers producing the quale assignable to these quantum numbers. Each metabolite carrying NE would define its own quale. One can assign metabolites also to hearing and vision: the metabolite would be assigned with sound waves or photons and carry NE. Whether the metabolite could be identified with dark phonons or photons is an interesting question.

4. Note that in this picture quantum number increment corresponds to that for a subsystem due to the flow of quantum numbers to it rather than to the change of quantum numbers in state function reduction. Hence it is possible to assign qualia also to quantum numbers rather than their increments.

5. Also in this framework the analog of thermodynamical description is suggestive since chemical potentials provide natural thermodynamical description for the numbers of ions. In ZEO square root of thermodynamics is highly suggestive in order to take into account the macroscopic quantum coherence in living systems and I have proposed a model of cell membrane along these lines generalizing the usual thermodynamical model [K31]. Chemical potentials are in this framework replaced with the cyclotron energy differences over cell membrane.

The association of sensory qualia with the transfer of metabolites of various kinds is a powerful prediction and conforms at least in spirit with the early very naive attempts to identify qualia in terms of biologically important charged particles assumed to form cyclotron condensates at dark magnetic flux tubes. If ATP (and GTP) are the universal carriers of metabolic energy and if energy quale must accompany any quale, one could try to identify the metabolites giving rise to qualia from the biochemistry of the sensory perception. The proposal that nutrients carry NE conforms with this picture.

3. "Final" solution to the problem of qualia

The TGD inspired theory of qualia [K12] has evolved gradually.

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

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

3. The view that emerged while writing the critics of IIT of Tononi [K41] is that qualia correspond to the quantum numbers measured in the state function reduction. That in ZEO the qualia remain the same for the entire sequence of repeated state function reductions is not a problem since qualia are associated with sub-self (sub-CD), which can have lifetime of say about .1 seconds! Only the generalization of standard quantum measurement theory is needed to reduce the qualia to fundamental physics. This for instance supports the conjecture that visual colors correspond to QCD color quantum numbers. This makes sense in TGD framework predicting a scaled variants of QCD type physics even in cellular length scales.

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

4.4.2 Questions about various kinds of entropies and negentropies

In standard positive energy ontology and in absence of dark matter second law is natural for many-particle systems. In ZEO and accepting the hierarchy of dark matters NMP replaces second law and the modification of thermodynamics replaced entropy with negentropy is highly suggestive.

Consider first the situation in positive energy ontology. There are three kinds of entropies and the basic question is how these entropies relate.

1. Does the entropy characterizing the experience of self relate to the thermodynamical entropy of some system? The fact that non-geometric sensory qualia have a statistical interpretation, suggests that the entropy associated with the qualia of the mental image corresponds to the thermodynamical entropy for a system giving rise to the qualia via the sensory mapping. The thermodynamics of quantities in the external world would thus be mapped to the thermodynamics of qualia, increments of quantities, in the inner world. Selves could also represent

the fundamental thermodynamical ensembles since they define also statistical averages of quantum numbers and zero modes although these are not directly experienced.

2. Could one interpret the entropies of the space-time sheets as entropies associated with the symbolic representations of conscious experiences of selves? Could one see the entire classical reality as a symbolic representation? Does the entropy of conscious experience correspond to the thermodynamical entropy of the perceived system, which in turn would correspond to the classical space-time entropy of the system representing the perceived system symbolically? Does this conclusion generalize to the case of p-adic entropy? Quantum-classical correspondence would encourage to cautiously think that the common answer to these questions might be yes.

One can repeat these questions almost as such for ZEO option. Now one would only speak about negentropy. Each quale would corresponding to its metabolite and to a chemical potential contribution to the differentials of thermodynamical functions. The thermodynamics of qualia could allow to have quantitative model correlating qualia with chemistry.

4.4.3 The arrow of psychological time and thermodynamics

In positive energy ontology and standard QM the arrow of psychological time is closely related to the second law and I have considered several alternative identifications for the arrow of psychological time. In ZEO [K26, K1] NMP replaces second law and the arrow of psychological time emerges as a prediction of the model for self as sequences of state function reductions to a fixed boundary of CD. The new element is that the arrow of geometric time chan change and that the moments for these changes define increases for the distance between the tips of CD defining a discrete flow of psychological time.

The latest option favored by ZEO involves two aspects. The one related to the arrow of time coordinate assignable to the space-time sheet and the other one to the relative proper time coordinate between the tips of CD. A simple argument show that this distance should increase gradually in statistical sense since the size of CD can also change in quantum jump. This would have have interpretation in terms of a flow of "cosmic time" (CD is analogous to big bang followed by big crunch). Interestingly, CD with time scale of order 10^{11} years (age of the universe) corresponds primary p-adic length scale of only only 10^{-4} meters, the size of a large neuron, and also the length scale in which the blob of water has Planck mass so that the quantization of gravitational Planck constant should become important [K22]. Could this mean that the CDs assignable to large neurons make possible to develop the idea about the cosmology and cosmology itself? Could it really be that that our cognitive representations about Universe quite concretely have the size of the Universe itself as p-adic view about cognition requires?

4.4.4 Reductionism, holism and NMP

The fusion of sub-selves can take place in two manners: by real bound state entanglement and by NE. The resulting mental images must differ somehow, and the proposal is that the entanglement associated with the negentropic mental defines a conscious cognitive representation: kind of rule. Schrödinger cat negentropically entangled with the bottle of poison knows that it is not a good idea to open the bottle: open bottle-dead cat, closed bottle-living cat (note that thew weak form of NMP allows the cat to open the bottle so that the information is useful!). NE would generate rules and counterparts of conscious associations fundamental in brain functioning. For the mental image associated with bound state entanglement the information about bound systems would be lost. NE could give rise to stereo-consciousness essential for (say) stereo vision.

Analysis and conceptualization (synthesis) - formation of rules- could be seen as the reductionistic and holistic aspects of consciousness. The interpretation of quantum jump as a creation of a totally entangled holistic state, which is then analyzed to stable entangled pieces allows to interpret self measurement cascade as a conscious analysis. The resulting stable negentropic pieces give rise to experience of understanding and conceptualization - rules and abstractions. Perhaps the holistic character assigned to right brain hemisphere could be interpreted in terms of specialization to conceptualization and reductionist character of left brain to analysis to smallest possible pieces. This picture proposed originally in positive energy ontology makes sense also in ZEO.

Could one assume that left brain generates entropic bound state entanglement and right brain NE? This idea not so feasible as it looked originally. The reason is that only NE might be relevant for consciousness.

In ZEO the sequence of state function reductions at passive boundary of CD generates entangled holistic state at the active boundary and the reduction to opposite boundary generates the reductionistic state at it. The two boundaries of CD would seem to correspond to the reductionistic and analytic aspects of consciousness. Again one must be very cautious in making interpretations. One can also consider that holistic state corresponds to NE in long scales and with large h_{eff} whereas the reductionistic state would correspond to short scales and small values of h_{eff}.

If left and right brain work independently they should not differ unless their magnetic bodies are different in the sense that right brain correspond to a large magnetic body and to large values of h_{eff} and left brain to small values of h_{eff}. Could it be that the brain hemispheres work together quantum coherently and this allows specialization?

Could left brain produce less NE than right brain? Could left brain be the bad boy and right brain the saint? Or do both produce NE but that NE corresponds to short p-adic length scales in the case of left brain (dimension d of final state projectior is a large power of small prime p) and long p-adic length scales in the case of right brain hemisphere (d is a small power of large p)?

There are rather interesting connections with altered states of consciousness and states of macro-temporal quantum coherence.

1. Making mind empty of mental images could perhaps be interpreted as a mechanism of achieving irreducible self state. If self entangles negentropically with larger conscious entity this would lead to experiences characterized as expansion of consciousness, even cosmic consciousness. One could also consider the possibility the sub-selves representing mental images fuse to single long-lasting negentropic mental image. The absence of dissipation could relate to the reports of meditators about lowered metabolic needs.

2. The ordinary wake-up consciousness is identifiable as the analytical mode in which NE in short scales dominates. Together with weak form of NMP this would suggest that state function reductions are carried out to rather sub-spaces with rather low dimension or alternatively to sub-spaces for which the dimension is larger power of small prime defining the p-adic length scale. The reason for this could be sensory input and motor activities, which would create effective heat bath destroying holistic mental images.

3. Krishnamurti has talked a lot about states of consciousness in which no separations and discriminations occur and timelessness prevails. These states could correspond to long-lived NE with large $\hbar$ with larger conscious entities giving rise to very long effective moments of consciousness. In this kind of situation NMP does not force cognitive self measurements to occur and analysis and separations can thus be avoided.

4. Sharing and fusion of mental images by entanglement of sub-selves of separate selves makes possible quantum realization of telepathy and could be a universal element of altered states of consciousness. Also this entanglement could be bound state entanglement or NE.

4.4.5 Cognitive codes

p-Adic length scale hypothesis leads to the idea that each $p \simeq 2^k$, k integer, defines a hierarchy of cognitive codes with code word having duration given by the n-ary p-adic time scale $T(n,k)$ and number of bits given by any factor of k. Especially interesting codes are those for which the number of bits is prime factor or power of prime factor of k. $n = 2$ seems to be in special position in ZEO. This is a strong quantitative prediction since the duration of both the code word and bit correspond to definite frequencies serving as signatures for the occurrence of commutations utilizing these codes.

If k is prime, the amount of information carried by the codon is maximal but there is no obvious manner to detect errors. If k is not prime there are several codes with various numbers of bits: information content is not maximal but it is possible to detect errors. For instance, $k = 252$ gives rise to code words for which the number of bits is $k_1 = 252, 126, 63,\ 84, 42, 21_2, 9,\ 7, 6_2, 4, 3_2, 2$: the subscript $_2$ tells that there are two non-equivalent manners to get this number of bits. For

instance, $126 = 42 \times 3$-bit codon can have 42 -bit parity codon: the bits of this codon would be products of three subsequent bits of 126-bit codon. This allows error detection by comparing the error codon for communicated codon and communicated error codon.

The recent view about how NMP selects preferred primes [K36] supports this idea. The values of dimension for the sub-space defining the outcome of reduction which are primes near powers of prime p are favoured by NMP. $p = 2$ gives the p-adic length scale hypothesis. Large powers of small prime could give rise to cognitive codes. Not that the integers associated with code could also be in the range $[0, p^n]$. For instance, for microtubules $p = 13$ is suggestive. For genetic code $p = 127$ is suggestive.

4.4.6 Abstraction hierarchy and genetic code

Mersenne primes $M_n = 2^n - 1$, which seem to play fundamental role in elementary particle physics. This would put primes 3, 7, 31, 127, etc. in a special position. Primes appear frequently in various bio-structures and this might reflect the underlying p-adicity for the association sequences providing "plan" for the development of bio-system. For instance, we have actually 7 (!) fingers: two of them have degenerated during evolution but can be seen in the developing embryo. There are 31 subunits in our spinal chord, etc...

As already explained, the emergence of primes near powers of prime can be understood from NMP.

In the model of genetic code based on a simple model of abstraction process [K13] the so called Combinatorial Hierarchy $2, 3, 7, 127, 2^{127} - 1, ...$ of Mersenne primes emerges naturally. The construction for a model of abstraction process proceeds as follows.

1. At lowest level there are two digits. The statements Yes and No.

2. At the next level one considers all Boolean statements about these two statements which can be regarded as maps from 2-element set to 2-element set. There are 4 of them. Throw one away and you get 3 statements.

3. At the next level one considers all Boolean statements about these 3 statements and the total number of them is 2^3. Throw one away and you get 7 statements. And so on.

In this case one obtains what might be interpreted as a hierarchy of statements about statements about... The mystery is why one statement must be thrown away at each level of the construction. The answer might relate to a concrete model of quantum computation. The emotional realization of this code in terms of subs-spaces of n-dimensional space allows to understand this. The reason is that the outcome of the state function reduction corresponds to any $n - k$ dimensional sub-space for a fixed choices of basis with $k = 1, ..., n - 1$. $k = 0$ is obviously excluded and the number of choices is $2^n - 1$ rather than 2^n.

An open problem is how the emotional realization of Boolean algebra is mapped to its fermionic representation. The task is to map in a natural manner the outcome of the state function reduction to a corresponding many-fermion state (in ZEO it would be pair of many-fermion states at opposite boundaries of CD having opposite quantum numbers). Is it really possible to map different levels (reductions and states) to each other?

4.4.7 Is the sum of p-adic negentropies equal to real entropy?

I ended almost by accident to a fascinating and almost trivial theorem. Adelic theorem for information would state that conscious information represented as sum of p-adic negentropies (entropies, which are negative) is equal to real entropy. The more conscious information, the larger the chaos in the environment as everyone can verify by just looking around.

This looks bad! Luckily, it turned out that this statement is true for rational probabilities only. For algebraic extensions it cannot be true as is easy to see. That negentropic entanglement is possible only for algebraic extensions of rationals conforms with the vision that algebraic extensions of rationals characterize evolutionary hierarchy. The rationals represent the lowest level at which there is zero amount of conscious information.

It is not completely obvious that the notion of p-adic negentropy indeed makes sense for algebraic extensions of rationals. A possible problem is caused by the fact that the decomposition

of algebraic integer to primes is not unique. Simple argument however strongly suggests that the various p-adic norms of the factors do not depend on the factorization. Also a formula for the difference of the total p-adic negentropy and real entropy is deduced.

1. p-Adic contribution to negentropy equals to real entropy for rational probabilities but not for algebraic probabilities

The following argument shows that p-adic negentropy equals to real entropy for rational probabilities.

1. The fusion of real physics and various p-adic physics (identified as correlates for cognition, imagination, and intentionality) to single coherent whole leads to what I call adelic physics [K36]. Adeles associated with given extension of rationals are Cartesian product of real number field with all p-adic number fields extended by the extension of rationals. Besides algebraic extensions also the extension by any root of e is possible since it induces finite-dimensional p-adic extension. One obtains hierarchy of adeles and of corresponding adelic physics interpreted as an evolutionary hierarchy.

   An important point is that p-adic Hilbert spaces exist only if one restricts the p-adic numbers to an algebraic extension of rationals having interpretation as numbers in any number field. This is due to the fact that sum of the p-adic valued probabilities can vanish for general p-adic numbers so that the norm of state can vanish. One can say that the Hilbert space of states is universal and is in the algebraic intersection of reality and various p-adicities.

2. Negentropy Maximization Principle (NMP) [K16] is the variational principle of consciousness in TGD framework reducing to quantum measurement theory in Zero Energy Ontology assuming adelic physics. One can define the p-adic counterparts of Shannon entropy for all finite-dimensional extensions of p-adic numbers, and the amazing fact is that these entropies can be negative and thus serve as measures for information rather than for lack of it. Furthermore, all non-vanishing p-adic negentropies are positive and the number of primes contributing to negentropy is finite since any algebraic number can be expressed using a generalization of prime number decomposition of rational number. These p-adic primes characterize given systen, say elementary particle.

   NMP states that the negentropy gain is maximal in the quantum jump defining state function reduction. How does one define the negentropy? As the sum of p-adic negentropies or as the sum of real negative negentropy plus the sum of p-adic negentropies? The latter option I proposed for some time ago without checking what one obtains.

3. The adelic theorem says that the norm of rational number is equal to the product of the inverses of its p-adic norms. The statement that the sum of real and p-adic negentropies is zero follows more or less as a statement that the logarithms of real norm and the product of p-adic norms for prime factors of rational sum up to zero.

   The core formula is adelic formula stating that the real norm of rational number is product of its p-adic norms. This implies that the logarithm of the rational number is sum over the logarithms of its p-adic norms. Since in p-adic entropy assigned to prime p logarithms of probabilities are replaced by their p-adic norms, this implies that for rational probabilities the real entropy equals to p-adic negentropy.

   It would seem that the negentropy appearing in the definition of NMP must be the sum of p-adic negentropies and real entropy should have interpretation as a measure for ignorance about the state of either entangled system. The sum of p-adic negentropies would serve as a measure for the information carried by a rule with superposed state pairs representingt the instances of the rule. The information would be conscious information and carried by the negentropically entangled system.

4. What about probabilities in algebraic extensions? The probabilities are now algebraic numbers. The induced p-adic norm $N_p(x)$ for n-dimensional extension of Q is defined as the determinant $det(x)$ of the linear map defined by multiplication with x. $det(x)$ is rational number. The corresponding p-adic norm is defined as the n:th root $N_p(det(x))^{1/n}$ of the ordinary p-adic norm. Root guarantees that the norm co-incides with the ordinary p-adic

norm for ordinary p-adic integers. One must perform now a factorization to algebraic primes. Below an argument is given that although the factorization to primes is not always unique, the product of p-adic norms for given algebraic rational defined as ratio of algebraic integers is unique.

The p-adic norms of probabilities are however always powers of primes so that the adelic formula *cannot* be true since on the real side one has logarithms of algebraic numbers and on the p-adic side only logarithms of primes.

What could be the interpretation?

1. If conscious information corresponds to $N - P$, it accompanies the emergence of algebraic extensions of rationals at the level of Hilbert space.

2. If N corresponds to conscious information, then at the lowest level conscious information is necessary accompanied by entropy but for algebraic extensions $N - P$ could be positive since N is maximized.

Both interpretations conform with the number theoretic vision about evolution. One expects that the value of real entropy correlates strongly with the value of negentropy. This would conform with the observation that large entropy seems to be a prerequisite for life by providing large number of states with degenerate energies providing large representative capacity. For instance, Jeremy England has made this proposal [I2]: I have commented this proposal from [L6] (see `http://tinyurl.com/zjp3bp6`).

2. Formula for the difference of total p-adic negentropy and real entanglement entropy

Can one write an explicit formula the difference of total p-adic entanglement negentropy (positive) and real entanglement entropy using prime factorization in finite dimensional algebraic extension (note that for algebraic numbers defining infinite-dimensional extension of rationals factorization does not even exist since one can write $a = \sqrt{a}\sqrt{a} = ...$)? This requires that total p-adic entropy is uniquely defined. There is a possible problem due to the non-uniqueness of the prime factorization.

1. For Dedekind rings, in particular rings of integers, there exists by definition a unique factorization of proper ideals to prime ideals (see `http://tinyurl.com/h3oufpp`). In contrast, the prime factorization in the extensions of Q is not always unique. Already for $Q(\sqrt{-5})$ one has $6 = 2 \times 3 = (1 + \sqrt{-5})(1 - \sqrt{-5})$ and the primes involved are not related by multiplication with units.

   Various factorizations are characterized by so called class group and class field theory (see `https://en.wikipedia.org/wiki/Class_field_theory`) is the branch of number theory studying factorizations in algebraic extensions of integer rings. Factorization is by definition unique for Euclidian domains. Euclidian domains allow by definition so called Euclidian function $f(x)$ having values in R_+ with the property that for any a and b one has either $a = qb$ or $a = qb + r$ with $f(r) < f(b)$. It seems that one cannot restrict to Euclidian domains in the recent situation.

2. Even when the factorization in the extension is not unique, one can hope that the product of various p-adic norms for the factors is same for all factorizations. Since the p-adic norm for the extensions of primes is induced by ordinary p-adic number this requires that the p-adic prime for which the induced p-adic norm differs from unity are same for all factorizations and that the products of p-adic norms differing from unity are same. This independence on the representative for factorization would be analogous to gauge invariance in physicist's conceptualization.

   The probabilities P_k belongs to a unique product of ideals labelled by primes of extension. The ideals are characterized by norms and if this norm is product of p-adic norms for any prime factorization as looks natural then the independence on the factorization follows. Number theorist can certainly immediately tell whether this is true. What is encouraging that for $Q(\sqrt{-5})$ $z = x + \sqrt{-5}y$ has determinant $det(z) = x^2 + 5y^2$ and for $z == 1 \pm \sqrt{-5}$ one has has $det(z) = 6$ so that for the products of p-adic norms for the factorizations $6 = 2 \times 3$ and $(1 + \sqrt{-5})(1 - \sqrt{-5})$ are equal.

3. If this this guess is true, one can write the the difference of total p-adic negentropy N and real entanglement entropy S as

$$N - S = \sum P_k log(\frac{P_k}{\prod_p N_p(P_k)}) \ . \tag{4.1}$$

Here $\prod_p N_p(P_k)$ would not depend on particular factorization. The condition $\sum P_k = 1$ poses an additional condition. It would be nice to understand whether $N - S \geq 0$ holds true generally and if not, what are the conditions guaranteeing this. The p-adic numbers of numerators of rationals involved give positive contributions to $N - S$ as the example $P_k = 1/N$ in rational case shows.

3. An ansatz for entanglement probabilities guaranteeing $N - S > 0$

What about entanglement probabilities in algebraic extension of rationals? In this case real number based entanglement entropy is not maximal since entanglement probablities are different. What can one say about p-adic entanglement negentropies: are they still maximal under some reasonable conditions? The logarithms involved depend on p-adic norms of probabilities and this is in the generic case just inverse of the power of p. Number theoretical universality suggests that entanglement probabilities are of form

$$P_i = \frac{a_i}{N}$$

with $\sum_i a_i = N$ with algebraic numbers a_i not involving natural numbers and thus having unit p-adic norm.

With this assumption the p-adic norms of P_i reduce to those of $1/N$ as for maximal rational entanglement. If this is the case the p-adic negentropy equals to $log(p^k)$ if p^k divides N. The total adelic negentropy equals to $log(N)$ and is maximal and has the same value as for rational probabilities equal to $1/N$.

The real entanglement entropy is now in general however smaller than $log(N)$, which would mean that p-adic negentropy is larger than the real entropy as conjectured earlier [K40] (see `http://tinyurl.com/jozwqxk`). For *rational* entanglement probabilities the generation of entanglement negentropy - conscious information during evolution - would be accompanied by a generation of equal entanglement entropy measuring the ignorance about what the negentropically entangled states representing selves are.

This conforms with the observation of Jeremy England that living matter is entropy producer [L7] (see `http://tinyurl.com/jff33xk`). For algebraic extensions of rationals this entropy could be however smaller than the total negentropy. Second law follows as a shadow of NMP if the real entanglement entropy corresponds to the thermodynamical entropy. Algebraic evolution would allow to generate conscious information faster than the environment is polluted, one might concretize! The higher the dimension of the algebraic extension rationals, the larger the difference could be and the future of the Universe might be brighter than one might expect by just looking around! Very consolating! One should however show that the above described situation can be realized as NMP strongly suggests before opening a bottle of champaigne.

4. Cloning of maximally negentropic states is possible: DNA replication as cloning of this kind of states?

In Facebook discussion with Bruno Marchal and Stephen King the notion of quantum cloning as copying of quantum state popped up and I ended up to ask about approximate cloning and got a nice link about which more below. From Wikipedia article (see `http://tinyurl.com/oyvklde`) one learns some interesting facts cloning. No-cloning theorem states that the cloning of *all* states by unitary time evolution of the tensor product system is not possible. It is however possible clone *orthogonal basis of states*. Does this have some deep meaning?

As a response to my question I got a link to an article of Lamourex et al (see `http://tinyurl.com/zq4kgda`) showing that the *cloning of entanglement* - to be distinguished from the cloning of quantum state - is not possible in the general case. Separability - the absence of entanglement - is

not preserved. Approximate cloning generates necessarily some entanglement in this case, and the authors give a lower bound for the remaining entanglement in case of an unentangled state pair.

The cloning of maximally entangled state is however possible. What makes this so interesting is that maximally negentropic entanglement for *rational* entanglement probabilities in TGD framework corresponds to maximal entanglement - entanglement probabilities form a matrix proportional to unit matrix- and just this entanglement is favored by Negentropy Maximization Principle. Could maximal entanglement be involved with say DNA replication? Could maximal negentropic entanglement for algebraic extensions of rationals allow cloning so that DNA entanglement negentropy could be larger than entanglement entropy?

The impossibility of cloning of entanglement in the general case makes impossible the transfer of information as any kind of entanglement. Maximal entanglement - and maybe be even negentropic entanglement maximal in p-adic sectors - could however make the communication without damaging the information at the source. Since conscious information is associated with p-adic sectors responsible for cognition, one could even allow the modification of the entanglement probabilities and thus of the real entanglement entropy in the communication process since the maximal p-adic negentropy depends only weakly on the entanglement probabilities.

NE is assigned with conscious experiences with positive emotional coloring: experience of understanding, experience of love, etc... There is an old finnish saying, which can be translated to "Shared joy is double joy!". Could the cloning of NE make possible generation of entanglement by loving attitude so that living entities would not be mere thieves trying to steal NE by killing and eating each other?

4.5 NMP And Quantum Computer Type Systems

In ZEO there are 3 basic matrices. U-matrix between zero energy states, M-matrices and defining entanglement coefficients between positive and negative energy states at opposite boundaries of CD. The mutually orthonormal M-matrices are assumed to be expressible as "square root" of a density matrix expressible as a product of a hermitian diagonal square root of density matrix and unitary S-matrix. Quantum theory can be see as a square root of thermodynamics in this framework.

The original mathematically attractive hypothesis that U-matrix has M-matrices as its rows turned out to be wrong. The physical picture about U-matrix as unitary matrix between states represented by M-matrices allowing also dispersion in the moduli space for the CDs with the passive boundary fixed leads with rather general assumptions to the identification of U-matrix as a representation for the unitary scalings of CDs [K30].

This is the original picture and every updating forces to challenge the earlier picture.

1. What about M-matrix? Can one really regard it as an orthonormal row of U or is M completely free? The defence for this assumption is that the orthonormality for hermitian square roots of density matrix is extremely powerful constraint. M-matrices could correspond to orthonormal basis of hermitian generators of some symmetry algebra. If symmetry algebra commutes with the S-matrix, the square roots of density matrices would be invariant under S-matrix. This assumption might be however physically unfeasible. Besides the hermitian basis one the degrees of freedom defined by the discrete moduli of CD with second (passive) boundary fixed would label M-matrices.

2. Weak form of NMP suggests that TGD Universe can be regarded as a quantum computer. CD as quantum computer is a local version of the same idea. Unitarity process U could relate closely to quantum computation. The state function reduction process represents a stepwise halting of the computation proceeding to shorter scales (sub-CDs) until the resulting states are either bound states or negentropically entangled states.

3. The question is whether it is U-matrix or M-matrix, which defines quantum computation. In other words, which kind of transitions do the repeated state functions leaving the passive boundary of CD and states at it invariant, correspond? It would seem that U-matrix is the correct identification since a repeated de-localization in the moduli space of CDs followed by a localization (but no reduction) is involved at the active boundary of CD. Note that the moduli of CD consist of discrete Lorentz boosts and proper time translations for CD. The

argument of [K30] suggests that S-matrix reduces to a unitary representation for the scalings of CD by a power of S-matrix assignable to the CD with minimal size: $S(n) = S^n$, where n characterizes the size scale of CD as a temporal distance between its tips. This makes possible quantum computations.

4. In ZEO quantum computation can be associated with the sequence of repeated reductions at fixed boundary of CD defining self. NE would be realized in terms of an entanglement characterized by a multiple of unitary matrix for a two-body system at the passive boundary of CD and would be stable during computation. The computation would end with a state function reduction at opposite boundary giving the outcome of the process. It could be a state with higher entanglement negentropy but weak form of NMP allows also ordinary state function reduction. Strong form of NMP would make the halting of the quantum computation impossible. Bio-systems would be especially attractive candidates for performers of quantum computation like processes.

5. The action of U-matrix in this picture would be trivial at the passive boundary and affect only the moduli of the upper boundary and the M-matrices. U-matrix cannot be however the direct counterpart of the ordinary S-matrix since there is non-trivial action in the moduli space of CDs. The matrix elements of U-matrix are however expressible in terms of S-matrix and the orthonormal basis of hermitian square roots of density matrices.

It is useful to list the basic differences with respect to ordinary quantum computation. Ordinary quantum computation utilizes unitary evolution of quantum states in positive energy ontology. In this case quantum coherence is extremely fragile. In TGD framework NMP and ZEO allow to circumvent this problem. The outcome of the computation is however realized at the level of dark matter unless ordinary state function reduction takes place. This means that n reductions from $2^n - 1$ correspond to computations, whose outcome can be verified with the existing technology. A further new element is that the computation is conscious and this aspect might be the important one in living matter.

4.5.1 How quantum computation in ZEO differs from ordinary quantum computation

Quantum computation in ZEO differs in several respects from ordinary quantum computation.

1. The time parameter defining quantum computation as a unitary time evolution in standard quantum physics disappears and corresponds to the U-matrix for single repeated reduction followed by a localization in moduli of the active boundary of CD (but no reduction at the active boundary). Large number of these steps occur. This process occurs for sub-CDs of given CD and the outcome of the quantum computation as seen by CD would be determined statistically from the distribution of the outcomes of state function reductions for over sub-CDs.

   One can assign to the quantum computation a duration equal to the increase of the proper time distance between the tips of CD. For instance, .1 seconds could be the time scale assignable to quantum computations possibly assignable to electrons.

   The hierarchies of CDs and Planck constants make possible zoomed up variants of quantum computations. This kind of zooming might be essential for intelligent behavior since it is useful to simulate dynamics of the external world in the time scales natural for brain and shorter than the time scale during which it is necessary to react in order to survive. The geometric duration of the shortest possible quantum computation is of order CP_2 time about 10^4 Planck times, if the simplest estimate is correct.

2. The classical space-time correlates for the quantum computation are four-dimensional unlike in the case of ordinary quantum computation. In living matter nerve pulses and EEG frequencies would be very natural correlates of this kind. The model for DNA as topological quantum computer [K7] has as its space-time correlates magnetic flux tubes connecting DNA nucleotides and lipids of nuclear and cell membranes defining the braiding coding for the topological quantum computation. Dynamical flow of lipids defines the braiding in time direction and the memory representation is in terms of the braiding of the flux tubes induced

by this flow. A good metaphor is in terms of dancers connected to a wall by threads. Dancing is the correlate for the running quantum computer program and the geometric entanglement of threads the correlate for the storage of the program to computer memory.

3. The outcome of quantum computation is described statistically in terms of a large set of quantum computations. The statistical description of the conscious experience of ensemble of sub-selves implies that mathematically the situation is very much analogous with that encountered in the standard quantum computation and it is attractive to assume that conscious experience codes for the outcome of quantum computation via the average quantities assignable to the distribution of zero energy quantum states assignable to sub-CDs.

4. A further new element is macro-temporal quantum coherence involving several aspects. One of these aspects is that the time scale of CD defines macrotemporal quantum coherence at least at the level of the field body assignable to the physical system such as electron. It is not quite clear whether electrons correspond to distinct overlapping CDs of size scale defined by.1 second time scale and of the order of Earth circumference and thus satisfying the basic criterion of quantum coherence or whether one should speak about anyonic many particle states assignable to single CD or whether both interpretations can make sense depending on situation.

   In living matter also millisecond time scale is important and would correspond naturally to the CDs assignable to u and d quarks in nuclei and perhaps also with the ends of magnetic flux tubes in the model of DNA as topological quantum computer. In the proposed model quarks and antiquarks at the ends of flux tubes represent genetic codons and their entanglement is responsible for the realization of the program at quantum level. The millisecond time scale of synchronous cortical firing and of nerve pulse could correspond to the time scale of CDs associated with u and d quarks at the ends of the flux tube. Note that larger value of $\hbar$ would scale up this time scale. Quantum parallel dissipation taking place at various size scales for CD is a further new element.

5. One must generalize the standard quantum computer paradigm since ordinary quantum computers represent only the lowest, 2-adic level of the p-adic intelligence. This suggests that qubits must be replaced by qupits since for algebraic entanglement two-state systems are naturally replaced with p-state systems. For primes of order say $p \simeq 2^{167}$ (the size of small bacterium) this means about 167 bits, which would mean gigantic quantum computational resources. The secondary p-adic time scale $T_2(127) \simeq .1$ seconds basic bit-like unit corresponds to $M_{127} = 2^{127}-1$ M_{127}-qupits making about 254 bits. The size of neuron corresponds to CD with time scale equal to the age of the universe and in this case the maximum the number of pinary digits is 171.

   The finite measurement resolution for qubits of course poses strong limitations to the actual number of bits since the negentropic zero energy qubits must be in reasonable approximation pure qubits distinguishable from each other and could correspond CDs with time scales coming as powers of two from $n = k_{min}$ to k so that the effective number of qubits would go like 2-based logarithm of the p-adic prime. For instance, electron could correspond to six bits assignable to genetic code plus parity bit corresponding to time scale range from 1 ms to 100 ms. In any case the idea about neuron as a classical bit might be completely wrong!

6. Spin glass degeneracy also provides the needed huge number of degrees of freedom making quantum computations very effective. These degrees of freedom are associated with the flux tubes -say magnetic flux tubes- and are essentially gravitational so that a connection with Penrose-Hameroff hypothesis suggests itself. The space-time sheets mediating gravitational interaction are predicted to have a huge gravitational Planck constant $\hbar_{gr} = GMm/v_0$, $v_0/c < 1$, particles at these space-time sheets are predicted to have huge Compton wavelengths and the plausible looking identification is in terms of dark energy [K22, K19]. This would make quantum computation like activities possible in super-astronomical time scales.

4.5.2 Negentropic quantum computations, fuzzy qubits, and quantum groups

(a) The possibility of NE is certainly the basic distinction making in the intersection of real and p-adic worlds possible a conscious process at least analogous to a quantum computation and accompanied by a conscious understanding. What makes this possible is the fact that the negentropically entangled states of N basic states have permutation of the basis states as a symmetry. For instance, states for which bit 1 appears with almost unit probability gives by permutation a state for which bit 0 appears with almost unit probability. This suggests that the outcome of quantum computation is expressed in terms of almost bits with a small mixing implying that the outcome has interpretation both as a rule and as almost bit in the ordinary sense. The conscious quantum computation would utilize states with NE in time direction. Also the analogies of bound states for time-like entanglement are possible and might make possible the counterpart of ordinary quantum computation without the higher level conscious experience about rules defined by the entangled states.

(b) NE for positive and negative energy parts of bits stable and pinary digits stable under NMP means that the logic is always fuzzy. I have proposed the mathematical description of this in terms of quantum spinors for which the components do not commute anymore implying that only the probability for either spin state is is an observable [K28]. This suggests that NE might be describable in terms of quantum spinors and that it would be the unavoidable fuzziness which would make possible the representation conscious rules. What is interesting that for quantum spinors the spectrum of the probabilities for given spin is universal and depends only on the integers characterizing the quantum phase $q = exp(i2\pi/n)$. An alternative interpretation is that fuzzy logic relates to a finite measurement resolution. These interpretation need not be in conflict with each other. Since quantum groups are associated with anyonic systems, this suggests that negentropic quantum computations take place in anyonic systems assignable to phases with large value of $\hbar$. This encourages to consider the possibility that quantum phases define algebraic extensions of p-adic numbers.

(c) In living systems it might be more appropriate to talk about conscious problem solving instead of quantum computation. In this framework the periods of macro-temporal quantum coherence replace the unitary time evolutions at the gates of the quantum computer as the basic information processing units and entanglement bridges between selves act as basic quantum communication units with the sharing of mental images providing a communication mode not possible in standard quantum mechanics.

4.6 Quantum Measurement And Quantum Computation In TGD Universe

It is interesting to test how the view about quantum computation must be modified in TGD Universe. There are considerable deviations from the standard view. Zero Energy Ontology (ZEO), weak form of NMP dictating the dynamics of state function reduction [K16], negentropic entanglement, and hierarchy of Planck constants [K34] define the basic differences between TGD based and standard quantum measurement theory. TGD suggests also the importance of topological quantum computation (TQC) like processes with braids represented as magnetic flux tubes/strings along them.

The natural question is how NMP and Zero Energy Ontology (ZEO) could affect the existing view about TQC. The basic observation is that the phase transition to dark matter phase reduces dramatically the noise affecting quantum quits. This together with robustness of braiding as TQC program raises excellent hopes about TQC in TGD Universe. The restriction to negentropic space-like entanglement (NE) defined by a unitary matrix is something new but does not seem to have any fatal consequences as the study of Shor's algorithm shows.

NMP strongly suggests that when a pair of systems - the ends of braid - suffer state function reduction, the NE must be transferred somehow from the system. How? The model for quantum teleportation allows to identify a possible mechanism allowing to achieve this. This

mechanism could be fundamental mechanism of information transfer also in living matter and phosphorylation could represent the transfer of NE according to this mechanism: the transfer of metabolic energy would be at deeper level transfer of negentropy. Quantum measurements could be actually seen as transfer of negentropy at deeper level.

NE defines an excellent candidate for an analog of error correcting code. If only the diagonal form of the unitary entanglement matrix carries information, the quantization of phases as roots of unity provides a scenario in which Nature itself would take care of error correction.

4.6.1 ZEO based quantum measurement theory

Consider first the quantum measurement theory based on ZEO.

(a) Sub-system–complement pair defining larger system defines the counterpart for the pair observer-measured system in standard quantum measurement theory. In TGD framework density matrix for a sub-system–complement pair defines the universal observable. As a matter of fact, for a given system all sub-system-complement pairs defining possible splitting of this kind and the state function reduction is realized for the pair giving rise to maximum of maximal negentropy gain (NMP). A further essential assumption is that the reduction proceeds from a system inside CDE to subsystems as a cascade obeying this basic rule.

(b) ZEO implies that state function reductions occur at either boundary of causal diamond (CD) - the active boundary. The sequence of reductions leaving passive boundary and state at it unaffected gives rise to a conscious entity - self. What is new that at the active boundary the state changes. Even the active boundary itself drifts to the geometric future so that the size of CD increases. This gives rise to the experience about flow of time.

This is the TGD counterpart for the unitary time evolution and its duration corresponds to the increases of the proper time distance between the tips of CD. Eventually NMP forces the first state function reduction to the opposite boundary: this corresponds to a genuine state function reduction. The self dies and re-incarnates at the opposite boundary as time reversed self since CD increases after than at the opposite boundary to the direction of geometric past.

In the standard quantum models for quantum computation one assumes that measurement can be realized by some interaction Hamiltonian: the state of entangled system-observer pair develops to an eigen state of the interaction Hamiltonian. The time development by this interaction Hamiltonian gives entangled state defined by the density matrix. This description can be seen as an approximation to TGD based description in which one can assign definite duration to the analog of the unitary evolution.

(c) Negentropic entanglement (NE) is possible for entanglement coefficients in algebraic extension of rationals since in this case number theoretic entropy having negative values is well-defined. If the density matrix does not belong to the same algebraic extension, state function reduction requires a phase transition extending the algebraic extension of rationals used and could be seen as kind of evolutionary jump. This kind of NE could be therefore rather stable and could be interpreted as a kind of cognitive entanglement representing a rule with instances represented as state pairs in the superposition. If the state function reduction occurs it leads to a ray of state space if density matrix is non-degenerate.

If the density matrix contains as a direct summand a higher-dimensional projector, a reduction giving rise to a projector to this sub-space is allowed by the interpretation as measurement of density matrix producing its eigen space. The state remains negentropically entangled by the unitary matrix giving rise to the projector. Weak form of NMP [K16] however allows reductions also to the subspaces of this sub-space assuming preferred state basis so that also the reduction to a ray of state space is possible as a special case. In this case any state basis is eigenbasis for the sub-space and this suggests an interpretation in terms of meditative states in which distinctions disappear.

4.6.2 TQC in TGD

How could (topological) quantum computation be realized in TGD framework?

(a) In standard quantum theory unitary time evolution realizes the quantum computation. Unitary time evolution is engineered in terms of gates performing standardized operations for qubits. For TQC braiding defines the space-time entanglement between the systems A and B at the ends of the braid. Call this system $A \otimes B$. One can speak about evolution a kind of "space-like" topological quantum computer program with negentropically entangled "initial" and "final" states at the ends of the braid. Basic braiding operation defines the basic gate in terms of so called R-matrix and the desired NE can be build using an appropriate braiding. For the sake of concreteness the following considerations assume TQC. In fact, if there is entanglement between ends, it must be unitary entanglement since only this entanglement is respected by NMP.

(b) In TQC the program is defined by braid and is robust against perturbations. The quantum states at the ends of the braid are however sensitive to noise and this requires complex error correction procedures to eliminate the errors, which are basically spin flip changing the value of qubit and change of its phase. If only phase ± 1 is allowed phase change actually reduces to spin flip in suitable basis.

In standard quantum computation the small value of Planck constant is the basic problem. Coherence times tend to be very short and the control of external noise is a tough challenge. In TGD quantum criticality gives rise to phases of matter with effective value $h_{eff} = n \times h$ of Planck constant identified as dark matter. These phases are involved also with NE. Only systems with same value of $h_{eff} = n \times h$ have direct interactions with each other. This should dramatically reduce the noise since visible matter particle must transform to dark matter particle to interact directly with dark matter to produce noise. Also the scaling up of interaction time scales gives hopes that quantum coherence times are long enough to perform TQC.

(c) The value of h_{eff} is expected to correlate with the duration of self defined as the increase ΔT of the temporal distance during the sequence of state function reductions to the same passive boundary of CD. ΔT could be interpreted as quantum coherence time. Coherence time for classical fields could be identified as the temporal distance between the tips of CD increasing during quantum computation.

(d) TGD promises to guarantee the reduction of noise in terms of darkness of the particles involved with the computation: this instability is the weakness of TQC although TQC program itself is robust. TGD also promises the understanding of the role of quantum criticality in quantum measurement. The very fact that quantum measurements necessarily involve the amplification of small quantum effects to macroscopic "classical" effect, indeed strongly suggests quantum criticality.

(e) The key challenge is to prepare a desired kind of negentropically entangled state - say a dark many-particle state associated with a braid system. One should be able to manipulate of dark matter, which we are not yet able to even detect! That dark matter appears at quantum criticality could be extremely helpful in the attempts to get grasp on the dark matter. A simple clue is that the disappearance of visible matter could serve as a signature for the emergence of dark matter.

One should somehow be able to perform state function reduction of the negentropically entangled system to one of the eigenstates of the density matrix associated with an entanglement matrix proportional to a unitary matrix (in the following I will speak of unitary entanglement). This requires TGD counter part of time evolution. One can imagine two options.

(a) One can couple the negentropically entangled system pair AB to a measurement apparatus C, whose function is to develop ordinary entanglement with both systems during the repeated sequence of state function reductions at fixed boundary. In the state function reduction to the opposite boundary a time reversed reduced state results and gives

rise to rays of state space for both A and B. One can however argue that the situation cannot be so simple: NMP requires that entanglement negentropy increases so that NE should be transferred somewhere. This will be discussed below.

(b) The measurement interaction must be able to achieve ordinary state function reduction by generating entanglement with the system formed by negentropically entangled system. One must have interaction between ordinary and dark matter and this requires transformation of ordinary matter to dark matter with the same value of h_{eff}. Quantum criticality allows the transformation of ordinary matter to dark matter so that the measuring system should be quantum critical [K34].

(c) Could one do without a third system? Weak form of NMP allows also a reduction to the lower dimensional sub-spaces of the N-D sub-space considered and also 1-D ray is possible. This process corresponds to a duration of single self, which dies when the first reduction to the opposite boundary of its CD occurs. If the braid system is not changed in the state function to the opposite boundary one can hope that a reduction to a 1-D ray can occur with some probability. By waiting long enough one can obtain state function reductions which determine the probabilities for the reduction to a given ray or sub-space. The important difference to the standard picture would be that the system does it itself. No external measurements at the end of braid would be carried out. This is however too good to be true. Only one of the two quantum measurements required by Shor algorithm can be both carried out in his manner.

The interpretation in terms of consciousness theory allows also to consider the possibility that the measurement corresponds at deeper level to transfer of negentropic entanglement.

(a) One has besides AB also the third system C. The NE for AB is transferred to NE for AC and can be transferred further - say to entanglement to NE for CD. In TGD framework the iteration of this process makes possible a transfer of conscious information associated with NE for AB to that of conscious observer.

(b) If the state of C is eigenstate of spin in the basis used, the final state of B is also an eigenstate of spin. Hence the transfer of NE could be thus interpreted as a measurement of the state of B or as the measurement of state of AC in Bell basis. This conforms with the fact that state function reduction for a subsystem can be interpreted as a state function reduction for its complement. Could the deeper interpretation of quantum measurement be as a transfer of NE so that essentially quantum information theory would be in question.

(c) The measurement is performed for the negentropically entangled Bell states for the pair AC and performs the transfer of entanglement inducing a unitary rotation. Since in the case of NE defined by a unitary matrix any state basis is allowed, one could ask whether the outcomes are equivalent from the point of view of consciousness theory at least. The knowledge of the final state of B allows to deduce the unitary rotation needed to rotate AC state to the original AB state so that this information is enough to realize a faithful NE transfer. Since the conscious experience is dictated both by the bit telling the state of B and by the state of AC one can ask whether the conscious experience and is same for all four outcomes.

4.6.3 Where and how the NE could be transferred?

NMP demands that entanglement negentropy increases. An interesting question is, where and how the entanglement negentropy is transferred.

(a) Does NE correspond to information transferred to the performer of quantum measurement? If so, the quantum measurement process would be basically transfer of information realized as NE. Living systems would be carrying out this all the time and ATP-ADP transformation defining the basic step of energy metabolism would be just this kind of transfer. The transfer corresponds at the level of space-time geometry the transfer of the end of magnetic flux tubes plus particles from a donor to the acceptor.

(b) A possible manner to carry out the transfer of negentropic entanglement is inspired by the quantum teleportation protocol (`https://en.wikipedia.org/wiki/Quantum_teleportation`). In the simplest situation this protocol is as follows. Alice wants to send qubit C to Bob. A Bell state (`https://en.wikipedia.org/wiki/Bell_state`) is shared between Alice and Bob by mutual agreement in advance so that both know it. Alice can achieve the teleportation by a quantum measurement in the tensor product of the qubit C with the AB Bell state.

Alice reduces the system AC to one of the four Bell states and communicates the result classically to Bob. The factored out state of B is the original state or one of three states related to it by unitary rotation. Alice sends classically two bits telling what the measurement outcome was. If the outcome was the original state to be sent, Bob does nothing. If it was one of the three remaining states, Bob performs a unitary rotation giving as a result the original state.

(c) What makes this protocol so interesting is that in the reduction the NE for AB is transferred to NE for AC as such or modified by a unitary rotation so that four different outcomes are possible. Since the states of C and AB are in 1-1-correspondence it is indeed obvious that the information about the state of B resulting from the measurement of Alice allows the rotation of the Bell state AC to the original state AB. For instance, if the state of B is the original state of C, the state is the original state AB.

One can apply this procedure by introducing four system D - call it Doris - so that AC NE is transferred to CD NE and AB is now product state. This kind of transfer of negentropic entanglement might be a key event in in phosphorylation and in the utilization of metabolic energy coming from nutrients. The NE between phosphate P of ATP ==B and third system A would be transferred to NE between acceptor molecule and C and A. Also the NE between nutrient B and third system A could be transferred to NE between phosphate and A.

4.6.4 Shor's algorithm from TGD point of view

Is the unitary of the entanglement matrix guaranteeing NE too strong an assumption? Just for fun I looked Shor's algorithm (`https://en.wikipedia.org/wiki/Shor's_algorithm`) for the factorization of a given integer, call it N, which has been shown to work for $N = 15$. It turns out that unitary entanglement is not a problem. Furthermore, ordinary quantum measurements are needed for the two systems involved and require interaction coupling negentropically entangled pair of systems to external world so that both negentropically entangled systems generate entanglement with external world.

Consider now the Shor's algorithm. The genuinely quantal step of algorithm is that of finding the period r of the function $f(x) = a^x \ mod \ N$, for integers $1 < a < N$ and $1 < x < N$.

(a) According to the Wikipedia article , the computation involves the construction of quantum function $f(x) = a^x$ as

$$\frac{1}{Q}\sum_x |x, f(x)\rangle \ .$$

Here Q is normalization factor. Since $a^r = 1 \ mod \ N$, $f(x)$ is not a bijection. Unless r divides Q (we do not however know r!), the number $N(z)$ of values of x satisfying $f(x) = z$ varies and the variation is one unit at most. Therefore the entanglement is not unitary and the density matrix of the state is not unit matrix since the norms of states

$$|Z| = \sum_x |x, f(x) = z\rangle$$

is given by $N(z)$- the number of x mapped to z and varies somewhat. NE would be obtained by normalizing the states $|Z\rangle$ to unit norm and replacing Q by the the number $N(Z)$ of points z to get

$$\frac{1}{\sqrt{N(Z)}}\sum_z \frac{1}{\sqrt{N(z)}}\sum_x |x, f(x)=z\rangle \ .$$

(b) Second step in the computation is discrete quantum Fourier transform using as counterparts of plane waves powers of the root of unity defined as $\omega = exp(i2\pi/Q)$, where Q satisfies $N^2 \leq Q < 2N^2$. This operation is unitary and gives rise to entanglement matrix proportional to a unitary matrix. Since the entire entanglement matrix is product of unitary matrices, it is also unitary. The action of unitary transformation is given for given value of z by the following formula.

$$\sum_x |x, f(x)=z)\rangle \rightarrow \sqrt{1}\sqrt{N}\sum_y \sum_{z=f(x)} \omega^{xy}|y, z=f(x)\rangle \ .$$

The entire state is transformed to

$$\frac{1}{\sqrt{N(Z)}}\frac{1}{\sqrt{N}}\sum_z \frac{1}{\sqrt{N(z)}}\sum_y \omega^{xy}\sum_x |y, z=f(x)\rangle \ .$$

In this expression the state paired $|Z\rangle$ is a superposition of several values of y since the number of different values of z is smaller than those of y by a factor which in ideal situation is the sought four value of r.

(c) Quantum measurement should reduce this state to a state with fixed values of y and z. This implies that the normalization factors do not matter. Weak NMP allows a self-reduction a state Z with fixed value of z. The self reduction of the system is however not able to reduce the state Z to $|y, z\rangle$.

One must couple at least the "y" part of the system to external measurement apparatus generating ordinary or negentropic entanglement with non-degenerate density matrix belonging to the extension used and having $|y\rangle$ as eigenstates. This would force y-reduction. One can of course perform the same for both y and z. The ordinary quantum measurement theory seems to be a necessary part of the picture. In TGD framework additional constraints come from the condition that the measurement involves negentropy transfer. This requires explicit introduce of systems C and D receiving the NE.

4.6.5 About negentropic entanglement as an analog of error correction code

In classical computation, the simplest manner to control errors is to take several copies of the bit sequences. In quantum case no-cloning theorem prevents this. Error correcting codes (`https://en.wikipedia.org/wiki/Quantum_error_correction`) code n information qubits to the entanglement of $N > n$ physical qubits. Additional contraints represents the subspace of n-qubits as a lower-dimensional sub-space of N qubits. This redundant representation is analogous to the use of parity bits. The failure of the constraint to be satisfied tells that the error is present and also the character of error. This makes possible the automatic correction of the error is simple enough - such as the change of the phase of spin state or or spin flip.

Negentropic entanglement (NE) obviously gives rise to a strong reduction in the number of states of tensor product. Consider a system consisting of two entangled systems consisting of N_1 and N_2 spins. Without any constraints the number of states in state basis is $2^{N_1} \times 2^{N_2}$ and one as $N_1 + N_2$ qubits. The elements of entanglement matrix can be written as $E_{A,B}$ $A \equiv \otimes_{i=1}^{N_1}(m_i, s_i)$, $B \equiv \otimes_{k=1}^{N_2}(m_k, s_k)$ in order to make manifest the tensor product structure. For simplicity one can consider the situation $N_1 = N_2 = N$.

The un-normalized general entanglement matrix is parametrized by 2×2^{2N} independent real numbers with each spin contributing two degrees of freedom. Entanglement matrix proportional to a unitary matrix is characterized by 2^{2N} real numbers. One might perhaps say that one has $2N$ real bits instead of almost $2N + 1$ real qubits. If the time evolution

according to ZEO respects the negentropic character of entanglement, the sources of errors are reduced dramatically.

The challenge is to understand what kind of errors NE eliminates and how the information bits are coded by it. NE is respected if the errors act as unitary transformations $E \to UEU^\dagger$ of the entanglement matrix unitary apart from a normalization factor. One can consider two interpretations.

(a) The unitary automorphisms leave information content unaffected only if they commute with E. In this case unitary automorphisms acting non-trivially would give rise genuine errors and an error correction mechanism would be needed and would be coded to quantum computer program.

(b) One can also consider the possibility that the unitary automorphisms *do not affect* the information content so that the diagonal form of entanglement matrix coded by N phases would carry of information. Clearly, the unitary automorphisms would act like gauge transformations. Nature would take care that no errors emerge. Of course, more dramatic things are in principle allowed by NMP: for instance, the entanglement matrix proportional to unitary matrix could reduce to a tensor product of several unitary matrices. Negentropy could be transferred from the system and is indeed transferred as the computation halts.

By number theoretic universality the diagonalized entanglement matrix would be parametrized by N roots of unity with each having n possible values so that n^N different NEs would be obtained and information storage capacity would be $I = log(n)/log(2) \times N$ bits for $n = 2^k$ one would have $k \times N$ bits. Powers of two for n are favored. Clearly the option for which only the eigenvalues of Ematter, looks more attractive realization of entanglement matrices. If overall phase of E does not matter as one expects, the number of full bits is $k \times N - 1$. This option looks more attractive realization of entanglement matrices.

In fact, Fermat polygons for which cosine and sine for the angle defining the polygon are expressible by iterating square root besides basic arithmetic operations for rationals (ruler and compass construction geometrically) correspond to integers, which are products of a power of two and of different Fermat primes $F_n = 2^{2^n} + 1$. 1

This picture can be related to much bigger picture.

(a) In TGD framework number theoretical universality requires discretization in terms of algebraic extension of rationals. This is not performed at space-time level but for the parameters characterizing space-time surfaces at the level of WCW. Strong form of holography is also essential and allows to consider partonic 2-surfaces and string world sheets as basic objects. Number theoretical universality (adelic physics) forces a discretization of phases and number theoretically allowed phases are roots of unity defined by some algebraic extension of rationals. Discretization can be also interpreted in terms of finite measurement resolution. Notice that the condition that roots of unity are in question realizes finite measurement resolution in the sense that errors have minimum size and are thus detectable.

(b) Hierarchy of quantum criticalities corresponds to a fractal inclusion hierarchy of isomorphic sub-algebras of the super-symplectic algebra acting as conformal gauge symmetries. The generators in the complement of this algebra can act as dynamical symmetries affecting the physical states. Infinite hierarchy of gauge symmetry breakings is the outcome and the weakening of measurement resolution would correspond to the reduction in the size of the broken gauge group. The hierarchy of quantum criticalities is accompanied by the hierarchy of measurement resolutions and hierarchy of effective Planck constants $h_{eff} = n \times h$.

(c) These hierarchies are argued to correspond to the hierarchy of inclusions for hyperfinite factors of type II_1 labelled by quantum phases and quantum groups. Inclusion defines finite measurement resolution since included sub-algebra does induce observable effects on the state. By Mac-Kay correspondence the hierarchy of inclusions is accompanied

by a hierarchy of simply laced Lie groups which get bigger as one climbs up in the hierarchy. There interpretation as genuine gauge groups does make sense since their sizes should be reduced. An attractive possibility is that these groups are factor groups G/H such that the normal subgroup H (necessarily so) is the gauge group and indeed gets smaller and G/H is the dynamical group identifiable as simply laced group which gets bigger. This would require that both G and H are infinite-dimensional groups. An interesting question is how they relate to the super-symplectic group assignable to "light-cone boundary" $\delta M^4_{\pm} \times CP_2$. I have proposed this interpretation in the context of WCW geometry earlier.

(d) Here I have spoken only about dynamical symmetries defined by discrete subgroups of simply laced groups. I have earlier considered the possibility that discrete symmetries provide a description of finite resolution, which would be equivalent with quantum group description.

Summarizing, these arguments boil down to the conjecture that discrete subgroups of these groups act as effective symmetry groups of entanglement matrices and realize finite quantum measurement resolution. A very deep connection between quantum information theory and these hierarchies would exist.

Gauge invariance has turned out to be a fundamental symmetry principle, and one can ask whether entanglement matrices proportional to unitary matrices assuming that only the eigenvalues matter, could give rise to a simulation of discrete gauge theories. The reduction of the information to that provided by the diagonal form be interpreted as an analog of gauge invariance?

(a) The hierarchy of inclusions of hyper-finite factors of type II_1 suggests strongly a hierarchy of effective gauge invariances characterizing measurement resolution realized in terms of hierarchy of normal subgroups and dynamical symmetries realized as coset groups G/H. Could these effective gauge symmetries allow to realize entanglement matrices proportional to unitary matrics invariant under these symmetries?

(b) A natural parametrization for single qubit errors is as rotations of qubit. If the error acts as a rotation on *all* qubits, the rotational invariance of the entanglement matrix defining the analog of S-matrix is enough to eliminate the effect on information processing.

Quaternionic unitary transformations act on qubits as unitary rotations. Could one assume that complex numbers as the coefficient field of QM is effectively replaced with quaternions? If so, the multiplication by unit quaternion for states would leave the physics and information content invariant just like the multiplication by a complex phase leaves it invariant in the standard quantum theory.

One could consider the possibility that quaternions act as a discretized version of local gauge symmetry affecting the information qubits and thus reducing further their number and thus also errors. This requires the introduction of the analog of gauge potential and coding of quantum information in terms of SU(2) gauge invariants. In discrete situation gauge potential would be replaced with a non-integrable phase factors along the links of a lattice in lattice gauge theory. In TGD framework the links would correspond the fermionic strings connecting partonic two-surfaces carrying the fundamental fermions at string ends as point like particles. Fermionic entanglement is indeed between the ends of these strings.

(c) Since entanglement is multilocal and quantum groups accompany the inclusion, one cannot avoid the question whether Yangian symmetry crucial for the formulation of quantum TGD [K25] could be involved.

5 Generalization Of Thermodynamics Allowing Ne And A Model For Conscious Information Processing

Costa de Beauregard considers a model for information processing by a computer based on an analogy with Carnot's heat engine [J3], [J3]. I am grateful for Stephen Paul King for bringing

this article to my attention in Time discussion group and also for inspiring discussions which also led to the birth of this section. As such the model Beauregard for computer does not look convincing as a model for what happens in biological information processing.

Combined with TGD based vision about living matter, the model however inspires a model for how conscious information is generated and how the second law of thermodynamics must be modified in TGD framework. The basic formulas of thermodynamics remain as such if the modification means only the replacement $S \to S - N$, where S is thermodynamical entropy and N the negentropy associated with negentropic entanglement.

Here one must be however very cautious since N and S are not directly comparable quantities (entanglement entropy is two-particle quantity and ensemble entropy single particle quantity). For ordinary state function reduction there two quantities seems to be however identical: state function reductions generate negentropy at single particle level and entropy at the level of ensemble. This modification would allows to circumvent the basic objections against the application of Beauregard's model to living systems.

The previous considerations suggest that second law is replaced with a statement that negentropy increases. The negentropy of dark matter is however unobservable using recent day technology and the safest assumption is that the entropy of living matter increases although phase transitions to dark matter occur spontaneously.

The earlier proposal was that second law still holds true was the most pessimistic that one can imagine and predicted that the negentropy produced is compensated as entropy. This assumption looks ad hoc but might allow to understand why living matter seems to be so effective entropy producer as compared to inanimate matter and also the characteristic decomposition of living systems to highly negentropic and entropic parts as a consequence of generalized second law.

5.1 Beauregard's Model For Computer

Beauregard's model describes computer as information processor analogous to heat engine. The work done by a heat engine is replaced with information generated by the computer and printing makes this information manifest.

(a) In Carnot cycle thermal energy is transformed to work and one obtains the well known upper bound for the efficiency from second law as $\eta = W/Q_{in} \leq \Delta T/T_{in}$.

(b) Beauregard a model for an ideal computer is as a system, which performs no work but prints instead. One studies information flow instead of energy flow. Negentropy is identified as a negative of thermodynamical entropy. Incoming negative negentropy flow means coding of program metaphorically at least and outgoing negentropy flow to what results, when this coding is erased in computer memory. The printed text carries the negentropy which in the optimal situation is the difference between incoming and outgoing negentropies. This negentropy is sucked from the incoming negative negentropy flow so that second law holds true.

(c) In terms of formulas one has $dW = dQ_{out} - dQ_{in} = 0$ and $dS = dQ_{out}/T_{out} - dQ_{in}/T_{in} = dQ_{in}(1/T_{out} - 1/T_{in}) \geq 0$. In the ideal case that the total entropy does not increase, this entropy growth must be compensated by the reduction of the entropy of the printer by amount dS interpreted as negentropy of the output.

(d) This vision about computing is based on second law and identifies information gain as difference between two entropies. System can gain information by feeding disorder to the environment. The best possible situation is that one has no information at all One can also wonder whether the output of the printer is really entropy.

5.1.1 Criticism of the model

This model seems consistent with thermodynamics and skeptic would argue that what we see around us could be seen as a support for this view about information processing in living

systems. One can however argue that the view about information as absence of entropy does not really make sense in living matter.

(a) NMP as fundamental law of consciousness suggests that negentropy increases when the printed text is read and negentropically entangled mental images are generated as subselves of self reading the text. The printed text would represent potentially conscious information.

(b) p-Adic physics encourages the belief in genuine information. If living matter is identified as something in the intersection of real and p-adic worlds it is possible to have a genuine information represented as a NE (see **Fig.** `http://tgdtheory.fi/appfigures/cat.jpg` or **Fig. ??** in the appendix of this book). The number theoretic variant of Shannon entropy gives a natural measure for this information since it can be negative and there is a unique p-adic prime minimizing it. Conscious information is a rule $A \leftrightarrow B$ in which the pairs $a \otimes b$ in the quantum superposition represent the instances of the rule. Schrödinger cat knows that it should not open the bottle by being a little bit dead but negentropically so.

(c) Second point is that Boltzmann's kinetic theory leading to the second law is based on the assumption that quantum coherence is not present in the time scales considered. If this assumption fails one cannot treat the system as a thermodynamical system (atoms represent standard example of this). In zero energy ontology and accepting the hierarchy of Planck constants, there are always levels of hierarchy for which second law does not make sense in a given time scale.

(d) There is also a direct experimental evidence for the reversal of thermodynamical time and therefore breaking of second law in time scales below.1 seconds, which happens to correspond to the time scale assignable to the CD of electron and to a fundamental biorhythm. The evidence comes from a system consisting of beads on necklace [D1].

   i. Standard physics explanation would be in terms of fluctuation in the value of entropy. Fluctuation theorem [B2] allows to deduce a precise expression for the ratio of probabilities of entropy fluctuations of same magnitude but opposite sign as $exp(A)$ where A represents the magnitude of the fluctuation. The appearance of.1 second time scale however forces to challenge this interpretation.

   ii. In TGD framework one possibility is that the spontaneous local reversal of the arrow of geometric time induced from that of experienced time implies that second law with reversed arrow of geometric time is operating. Second possibility is that genuine increase of negentropy is in question.

5.1.2 Problems of Beauregard's model if interpreted as a model for information processing in living systems

Beauregard's model for what he calls "printer" looks problematic for several reasons.

(a) Living matter and computers are in good approximation at the same temperature as environment and temperature T and volume V are not changed during the process so that free energy F is minimized rather than thermodynamical negentropy. This kind of systems are not analogous to steam engines for which one has has incoming steam at higher temperature. Beauregard's analog of Carnot engine satisfies $dW = dQ_{out} - dQ_{in} = 0$ and indeed gives for $T_{in} = T_{out}$ the trivial result $dN = 0$. No information is generated. Even worse, living systems are typically at higher temperature than environment so that the heat engine analogy does not seem to work well.

(b) In the analog of steam engine one actually assumes that the entropy difference for outgoing and incoming beams corresponds to a positive negentropy assignable to the printing. One can however treat the printer and computer as a single system in which case one can draw only one conclusion from standard thermodynamics: this negentropy corresponds to work done by the combined system and one has just the ideal steam engine but the work interpreted as printout. Something however distinguishes between printer and steam engine.

5.2 TGD Based Variant Of Beauregard's Model And Generalization Of Thermodynamics

The TGD inspired variant of Beauregard's model leads naturally to a generalization of the second law of thermodynamics taking into account the possibility of negentropic entanglement.

5.2.1 Questions

Something distinguishes between printer and steam engine and standard thermodynamics is not able to express this difference. What this something is? The proposal to be discussed is that the positive entanglement negentropy assignable to rational (or even algebraic) entanglement generated in the process in which conscious information is created. It is best to proceed by making questions.

(a) The work done by steam engine is "useful" work. What does this mean? Something which does not have meaning for us but is a prerequisite for having meaning. Perhaps metabolic energy at the basic level. This work can be eventually transformed to metabolic energy needed to build mental images generated by the text.

(b) What metabolic energy is? In TGD Universe there are two kinds of entanglements: the entropic bound state entanglement and NE which is rational or even algebraic and possible in the intersection of real and p-adic worlds. Bound state entanglement is stable under NMP by binding energy. This kind of entanglement is like a marriage based on social conventions, a jail.

Negentropic entanglement does not involve binding energy and can be compared to a marriage based on freedom and love. The positive energy associated with the negentropic entanglement has wrong sign to be interpreted as binding energy and is identifiable as metabolic energy. This identification could explain the long standing mystery of the high energy phosphate bond central for the functioning of ATP and ADP. ATP-ADP process would be basically a transfer of NE and thus information to the living system and at work at all levels in living matter.

Why living systems must the gain NE? To stay alive! The reason is NMP. If they are not able to generated NE assignable to subselves NMP forces the state function reduction at the opposite boundary of CD of self, which means death of self. This means generation of NE on the average but at the level of self.

(c) What is the process giving meaning to the text? This process must generate NE. The corresponding entanglement negentropy is something independent of thermodynamic entropy. The most pessimistic assumption is that the generation of NE is accompanied by the generation of thermodynamical entropy at least compensating it so that second law in a generalized form continues to hold true. It must be however emphasized that I am not able to really justify this assumption.

5.2.2 Modification of thermodynamics to take into account negentropic entanglement

What does the presence of this NE mean from the point of view of thermodynamics? NMP replaces second law and entanglement negentropy increases but NE invisible using the recent measurement technology but is experienced only consciously. The transformation of visible matter to dark matter seems to reduce entropy typically proportional to particle number. The pessimistic option is that the generation of negentropy is accompanied by a generation of at least the same amount of entropy in visible sector. In any case, the good news would be that dark matter carries the negentropy.

(a) One must generalize the basic expression for energy differential

$$dE = TdS - dW \rightarrow T(dS - dN) - dW \ . \tag{5.1}$$

This means that there are two kinds of energies given out by the system. The useful work dW and negentropic energy TdN. For steam engine only dW is present. For ideal system only negentropic energy would be present.

(b) What happens to the second law?
The naive arguments already considered suggest

$$\Delta S - \Delta N \leq 0 \ , \tag{5.2}$$

when the presence of dark matter is taken into account.
The probably over-pessimistic guess is that generation of negentropy requires a generation of at least same amount of entropy so that one would have

$$\Delta S - \Delta N \geq 0 \ . \tag{5.3}$$

Here S can be interpreted as a sum of two terms. The first part corresponds to the ensemble entropy generated by the randomness of ordinary quantum jumps, and second part to the entropy assignable as maximal entanglement entropy assignable to the decompositions of bound state to two parts. N corresponds to maximal negentropy for the decompositions of negentropic sub-system to pairs. One can criticize these definitions and a possible modification of could be as as the average for the entanglement entropies over this kind of decompositions.

(c) Quite generally, Clausius inequality allowing to deduce extremization conditions for various thermodynamical potentials generalizes to

$$T_0(\Delta S - \Delta N) - \Delta E - P_0 \Delta V \geq 0 \ . \tag{5.4}$$

where T_0 and P_0 and temperature and pressure of heat bath. Living systems would be entropy producers and this seems to conform with what we see around us.
For instance, for a system in constant volume one would have

$$\Delta S - \Delta N - \frac{\Delta E}{T} \geq 0 \ . \tag{5.5}$$

so that systems developing negentropy would also generate thermodynamics entropy. For a system in heat bath one has $T = T_0$ and Clausius inequality gives

$$\Delta F = -\Delta W \tag{5.6}$$

stating that increase of free energy at constant temperature requires work done on the system ($dW < 0$): otherwise $\Delta F \leq 0$ holds true.

By using the variable $S - N$ instead of S all formulas reduce formally to standard thermodynamics except that S can be negative. This is absolutely crucial for distinguishing TGD counterpart of Beauregard's printer -identifiable as conscious reader rather than printer - from Carnot engine.

5.2.3 The analog of Carnot cycle for information processing in living matter

Consider first Carnot heat engine and its information theoretic analog in standard thermodynamics.

(a) The basic equations for Carnot engine are

$$\begin{aligned} dW &= dQ_{out} - dQ_{in} = 0 \ \text{(ideal case)} \ , \\ d(S-N) &= \frac{dQ_{out}}{T_{out}} - \frac{dQ_{in}}{T_{in}} = dQ_{in}(\frac{1}{T_{out}} - \frac{1}{T_{in}}) \ . \end{aligned} \tag{5.7}$$

Depending on whether one assumes optimistic resp. pessimistic option one has $d(S-N) \leq 0$ resp. $d(S-N) \geq 0$.

(b) For the optimistic option, which should be realized in living matter one must have $T_{out} > T_{in}$ in order tos satisfy the latter condition. For pessimistic option one must have $T_{in} > T_{out}$. This supports the view that the optimistic option is correct. Now that also $dW > 0$ is possible for the optimistic option.

(c) Beauregard calls the information engine printer. What does this "printing" correspond from the point of view of NE? Is the NE is generated during physical printing or during the reading? If the NE is generated before reading, there must be some other conscious entity for which the text has meaning. This seems un-necessary assumption so that ordinary computers would not generate NE. For the second and much more reasonable looking option the above process takes place during the reading and the "printing" as a name for the above process is misleading: conscious reading is in question.

5.2.4 Some clarifying comments

Some clarifying comments about biological implications are in order. Many of them are inspired by the questions of Stephen Paul King in Time discussion group.

(a) There is no need to restrict the consideration to equilibrium systems. First of all, the environment and living system are in general at different temperatures and temperature difference is typically of wrong sign for the model of Beauregard to work in this context. Beauregard's model is of course a model for computation, not for the generation of negentropic mental images. Maybe cognitive machine might be proper term for what the modified model could describe.

(b) Quite generally, self-organization requires a feed of energy to the system so that one has flow equilibrium. In the case of living system this feed of energy is metabolic energy associated with the NE transferred to the system in the ATP-ADP process. Self-organization driven by NE leads to standardized negentropic mental images automatically as asymptotic self-organization patterns in 4-D sense (CDs within CDs within ...). The reason why NMP demands metabolic energy feed identifiable as feed of negentropic entanglement has been already considered.

(c) No explicit assumptions about computational aspects of the process has been made. Just a generation of conscious information identified in terms of NE is assumed. The basic character quantum jump as U-process followed by the cascade of state function reductions represents a fractal hierarchy of what can be seen as quantum computations and are distinguished from classical computations in that the process proceeds from top to bottom rather than being a local process. The result of computation is represented using statistical ensembles defined by sub-CDs at various levels of the hierarchy and is in principle communicable by classical fields (say EEG patterns in the case of brain) to higher levels of self hierarchy which in turn can induces the same distributions so that communication of the objective aspects of the experience with the mediation of "medium" is possible. The presence of the "medium" seems unavoidable. Magnetic body would be this medium in TGD inspired biology.

5.3 About Biological Implications Of Generalized Second Law

Generalized second law allows to sharpen the basic picture about implications of the second law.

Living matter might obey the generalized second law obtained by the replacement $S \to S-N$ and by optimistic assumption $dS - N \leq 0$, which need not hold true always. On the other hand, living matter produces entropy through excretion - an essential aspect of what it is to be alive - and this forces to as whether the pessimistic option $dS - N \geq 0$ holds true. This is not needed. The metabolic machinery takes the NE of nutrients and the outcome - excretion - consists of the matter lost its NE. Thus the easy to manner to gain NE causes excretion.

This picture seems to be in accordance with basic chemistry of energy metabolism.

(a) The process extraction negentropy from nutrients is standardized in living matter and mean a generation of high energy phosphate bonds assignable to AMP, ADP, and ATP containing 1, 2, and 3 phosphates respectively besides the sugar residue. Sugar residue is basic nutrient and would provide the stored metabolic energy transformed to the energy of the high energy phosphate bonds if the proposed view is correct. Also other DNA nucleotides such as G can appear besides A but in metabolism A has a preferred role. What is essential is that NE is transferred. Energy transfer is only a secondary aspect.

(b) The basic metabolic cycle provides ADP with an additional phosphate energizing it to ATP and the reverse process transfers the metabolic energy and also negentropic entanglement to the acceptor molecule. Also ADP can provide metabolic energy by transforming to AMP when ATP is not available in sufficient amounts. That the catabolism of AMP creates urea excreted out of the system fits with the general picture. The catabolism for nutrients would create the entropy compensating for the negentropy of the high energy phosphate bonds.

(c) The backbone of DNA is made of sugar and phosphate residues and corresponds to a sequence of XMP, $X = A, T, C, G$ with each XMP presumably containing single high energy phosphate bond serving as a storage or potential source of negentropy. This conforms with the view that DNA carries conscious or potentially conscious information.

Negentropic and entropic entanglement are assumed to generate mental images with opposite emotional colors. This connects information processing with emotions. From neuroscience point of view this is not a news: peptides are molecules of emotions on one hand and molecules of information on the other hand [J2]. The well-known specialization of the left and right hand sides of the amygdala to experience positive and negatively colored emotions could be seen as one instance of this connection and representing also an example about fractal negentropic-entropic differentiation. The realization of Boolean algebra in terms of the outcomes of state function reduction would realized the connection between emotions and information at basic level.

6 p-Adic physics and consciousness

p-Adic physics as physics of cognition and imagination is an important thread in TGD inspired theory of consciousness. In the sequel I describe briefly the basic of TGD inspired theory of consciousness as generalization of quantum measurement theory to ZEO (ZEO), describe the definition of self, consider the question whether NMP is needed as a separate principle or whether it is implied is in statistical sense by the unavoidable statistical increase of $n = h_{eff}/h$ if identified as a factor of the dimension of Galois group extension of rationals defining the adeles, and finally summarize the vision about how p-adic physics serves as a correlate of cognition and imagination.

6.1 From quantum measurement theory to a theory of consciousness

The notion of self can be seen as a generalization of the poorly defined definition of the notion of observer in quantum physics. In the following I take the role of skeptic trying to be as critical as possible.

The original definition of self was as a subsystem able to remain unentangled under state function reductions associated with subsequent quantum jumps. The density matrix was assumed to define the universal observable. Note that a density matrix, which is power series of a product of matrices representing commuting observables has in the generic case eigenstates, which are simultaneous eigenstates of all observables. Second aspect of self was assumed to be the integration of subsequent quantum jumps to coherent whole giving rise to the experienced flow of time.

The precise identification of self allowing to understand both of these aspects turned out to be difficult problem. I became aware the solution of the problem in terms of ZEO (ZEO) only rather recently (2014).

(a) Self corresponds to a sequence of quantum jumps integrating to single unit as in the original proposal, but these quantum jumps correspond to state function reductions to a fixed boundary of causal diamond CD leaving the corresponding parts of zero energy states invariant - "small" state function reductions. The parts of zero energy states at second boundary of CD change and even the position of the tip of the opposite boundary changes: one actually has wave function over positions of second boundary (CD sizes roughly) and this wave function changes. In positive energy ontology these repeated state function reductions would have no effect on the state (Zeno effect) but in TGD framework there occurs a change for the second boundary and gives rise to the experienced flow of time and its arrow and self: self is generalized Zeno effect.

(b) The first quantum jump to the opposite boundary corresponds to the act of "free will" or birth of re-incarnated self. Hence the act of "free will" changes the arrow of psychological time at some level of hierarchy of CDs. The first reduction to the opposite boundary of CD means "death" of self and "re-incarnation" of time-reversed self at opposite boundary at which the the temporal distance between the tips of CD increases in opposite direction. The sequence of selves and time reversed selves is analogous to a cosmic expansion for CD. The repeated birth and death of mental images could correspond to this sequence at the level of sub-selves.

(c) This allows to understand the relationship between subjective and geometric time and how the arrow of and flow of clock time (psychological time) emerge. The average distance between the tips of CD increases on the average as along as state function functions occur repeatedly at the fixed boundary: situation is analogous to that in diffusion. The localization of contents of conscious experience to boundary of CD gives rise to the illusion that universe is 3-dimensional. The possibility of memories made possibly by hierarchy of CDs demonstrates that this is not the case. Self is simply the sequence of state function reductions at same boundary of CD remaining fixed and the lifetime of self is the total growth of the average temporal distance between the tips of CD.

One can identify several rather abstract state function reductions selecting a sector of WCW.

(a) There are quantum measurements inducing localization in the moduli space of CDs with passive boundary and states at it fixed. In particular, a localization in the moduli characterizing the Lorentz transform of the upper tip of CD would be measured. The measured moduli characterize also the analog of symplectic form in M^4 strongly suggested by twistor lift of TGD - that is the rest system (time axis) and spin quantization axes. Of course, also other kinds of reductions are possible.

(b) Also a localization to an extension of rationals defining the adeles should occur. Could the value of $n = h_{eff}/h$ be observable? The value of n for given space-time surface at the active boundary of CD could be identified as the order of the smallest Galois group

containing all Galois groups assignable to 3-surfaces at the boundary. The superposition of space-time surface would not be eigenstate of n at active boundary unless localization occurs. It is not obvious whether this is consistent with a fixe value of n at passive boundary.

The measured value of n could be larger or smaller than the value of n at the passive boundary of CD but in statistical sense n would increase by the analogy with diffusion on half line defined by non-negative integers. The distance from the origin unavoidably increases in statistical sense. This would imply evolution as increase of maximal value of negentropy and generation of quantum coherence in increasingly longer scales.

(c) A further abstract choice corresponds to the the replacement of the roles of active and passive boundary of CD changing the arrow of clock time and correspond to a death of self and re-incarnation as time-reversed self.

Can one assume that these measurements reduce to measurements of a density matrix of either entangled system as assumed in the earlier formulation of NMP, or should one allow both options. This question actually applies to all quantum measurements and leads to a fundamental philosophical questions unavoidable in all consciousness theories.

(a) Do all measurements involve entanglement between the moduli or extensions of two CDs reduced in the measurement of the density matrix? Non-diagonal entanglement would allow final states states, which are not eigenstates of moduli or of n: this looks strange. This could also lead to an infinite regress since it seems that one must assume endless hierarchy of entangled CDs so that the reduction sequence would proceed from top to bottom. It looks natural to regard single CD as a sub-Universe.

For instance, if a selection of quantization axis of color hypercharge and isospin (localization in the twistor space of CP_2) is involved, one would have an outcome corresponding to a quantum superposition of measurements with different color quantization axis!

Going philosophical, one can also argue, that the measurement of density matrix is only a reaction to environment and does not allow intentional free will.

(b) Can one assume that a mere localization in the moduli space or for the extension of rationals (producing an eigenstate of n) takes place for a fixed CD - a kind of self measurement possible for even unentangled system? If there is entanglement in these degrees of freedom between two systems (say CDs), it would be reduced in these self measurements but the outcome would not be an eigenstate of density matrix. An interpretation as a realization of intention would be approriate.

(c) If one allows both options, the interpretation would be that state function reduction as a measurement of density matrix is only a reaction to environment and self-measurement represents a realization of intention.

(d) Self measurements would occur at higher level say as a selection of quantization axis, localization in the moduli space of CD, or selection of extension of rationals. A possible general rule is that measurements at space-time level are reactions as measurements of density matrix whereas a selection of a sector of WCW would be an intentional action. This because formally the quantum states at the level of WCW are as modes of classical WCW spinor field single particle states.

(e) If the selections of sectors of WCW at active boundary of CD commute with observables, whose eigenstates appear at passive boundary (briefly *passive observables*) meaning that time reversal commutes with them - they can occur repeatedly during the reduction sequence and self as a generalized Zeno effect makes sense.

If the selections of WCW sectors at active boundary do not commute with passive observables then volition as a choice of sector of WCW must change the arrow of time. Libet's findings show that conscious choice induces neural activity for a fraction of second before the conscious choice. This would imply the correspondences *"big" measurement changing the arrow of time - self-measurement at the level of WCW - intentional action* and *"small" measurement - measurement at space-time level - reaction.*

Self as a generalized Zeno effect makes sense only if there are active commuting with passive observables. If the passive observables form a maximal set, the new active observables commuting with them must emerge. The increase of the size of extension of rationals might generate them by expanding the state space so that self would survive only as long at it evolves.

Otherwise there would be only single unitary time evolution followed by a reduction to opposite boundary. This makes sense only if the sequence of "big" reductions for sub-selves can give rise to the time flow experienced by self: the birth and death of mental images would give rise to flow of time of self.

A hierarchical process starting from given CD and proceeding downwards to shorter scales and stopping when the entanglement is stable is highly suggestive and favors self measurements. What stability could mean will be discussed in the next section. CDs would be a correlate for self hierarchy. One can say also something about the anatomy and correlates of self hierarchy.

(a) Self experiences its sub-selves as mental images and even we would represent mental images of some higher level collective self. Everything is conscious but consciousness can be lost or at least it is not possible to have memory about it. The flow of consciousness for a given self could be due to the quantum jump sequences performed by its sub-selves giving rise to mental images.

(b) By quantum classical correspondence self has also space-time correlates. One can visualize sub-self as a space-time sheet "glued" by topological sum to the space-time sheet of self. Subsystem is not described as a tensor factor as in the standard description of subsystems. Also sub-selves of selves can entangle negentropically and this gives rise to a sharing of mental images about which stereo vision would be basic example. Quite generally, one could speak of stereo consciousness. Also the experiences of sensed presence [J7] could be understood as a sharing of mental images between brain hemispheres, which are not themselves entangled. This is possible also between different brains. In the normal situation brain hemispheres are entangled.

(c) At the level of 8-dimensional imbedding space the natural correlate of self would be CD (causal diamond). At the level of space-time the correlate would be space-time sheet or light-like 3-surface. The contents of consciousness of self would be determined by the space-time sheets in the interior of CD. Without further restrictions the experience of self would be essentially four-dimensional. Memories would be like sensory experiences except that they would be about the geometric past and for some reason are not usually colored by sensory qualia. For instance .1 second time scale defining sensory chronon corresponds to the secondary p-adic time scale characterizing the size of electron's CD (Mersenne prime M_{127}), which suggests that Cooper pairs of electrons are essential for the sensory qualia.

6.2 NMP and self

The view about Negentropy Maximization Principle (NMP) [K16] has co-evolved with the notion of self and I have considered many variants of NMP.

(a) The original formulation of NMP was in positive energy ontology and made same predictions as standard quantum measurement theory. The new element was that the density matrix of sub-system defines the fundamental observable and the system goes to its eigenstate in state function reduction. As found, the localizations at to WCW sectors define what might be called self-measurements and identifiable as active volitions rather than reactions.

(b) In p-adic physics one can assign with rational and even algebraic entanglement probabilities number theoretical entanglement negentropy (NEN) satisfying the same basic axioms as the ordinary Shannon entropy but having negative values and therefore having interpretation as information. The definition of p-adic negentropy (real valued) reads as $S_p = -\sum P_k log(|P_k|_p)$, where $|.|_p$ denotes p-adic norm. The news is that $N_p = -S_p$ can

be positive and is positive for rational entanglement probabilities. Real entanglement entropy S is always non-negative.

NMP would force the generation of negentropic entanglement (NE) and stabilize it. NNE resources of the Universe - one might call them Akashic records- would steadily increase.

(c) A decisive step of progress was the realization is that NTU forces all states in adelic physics to have entanglement coefficients in some extension of rationals inducing finite-D extension of p-adic numbers. The same entanglement can be characterized by real entropy S and p-adic negentropies N_p, which can be positive. One can define also total p-adic negentropy: $N = \sum_p N_p$ for all p and total negentropy $N_{tot} = N - S$.

For rational entanglement probabilities it is easy to demonstrate that the generalization of adelic theorem holds true: $N_{tot} = N - S = 0$. NMP based on N_{tot} rather than N would not say anything about rational entanglement. For extensions of rationals it is easy to find that $N - S > 0$ is possible if entanglement probabilities are of form X_i/n with $|X_i|_p = 1$ and n integer [L7]. Should one identify the total negentropy as difference $N_{tot} = N - S$ or as $N_{tot} = N$?

Irrespective of answer, large p-adic negentropy seems to force large real entropy: this nicely correlates with the paradoxical finding that living systems tend to be entropic although one would expect just the oppositecite [L7]: this relates in very interesting manner to the work of biologists Jeremy England [I2]. The negentropy would be cognitive negentropy and not visible for ordinary physics.

(d) The latest step in the evolution of ideas NMP was the question whether NMP follows from number theory alone just as second law follows form probability theory! This irritates theoretician's ego but is victory for theory. The dimension n of extension is positive integer and cannot but grow in statistical sense in evolution! Since one expects that the maximal value of negentropy (define as $N-S$) must increase with n. Negentropy must increase in long run.

6.2.1 Number theoretic entanglement can be stable

Number theoretical Shannon entropy can serve as a measure for genuine information assignable to a pair of entanglement systems [K16]. Entanglement with coefficients in the extension is always negentropic if entanglement negentropy comes from p-adic sectors only. It can be negentropic if negentropy is defined as the difference of p-adic negentropy and real entropy.

The diagonalized density matrix need not belong to the algebraic extension since the probabilities defining its diagonal elements are eigenvalues of the density matrix as roots of N:th order polynomial, which in the generic case requires n-dimensional algebraic extension of rationals. One can argue that since diagonalization is not possible, also state function reduction selecting one of the eigenstates is impossible unless a phase transition increasing the dimension of algebraic extension used occurs simultaneously. This kind of NE could give rise to cognitive entanglement.

There is also a special kind of NE, which can result if one requires that density matrix serves a universal observable in state function reduction. The outcome of reduction must be an eigen space of density matrix, which is projector to this subspace acting as identity matrix inside it. This kind NE allows all unitarily related basis as eigenstate basis (unitary transformations must belong to the algebraic extension). This kind of NE could serve as a correlate for "enlightened" states of consciousness. Schrödingers cat is in this kind of state stably in superposition of dead and alive and state basis obtained by unitary rotation from this basis is equally good. One can say that there are no discriminations in this state, and this is what is claimed about "enlightened" states too.

The vision about number theoretical evolution suggests that NMP forces the generation of NE resources as NE assignable to the "passive" boundary of CD for which no changes occur during sequence of state function reductions defining self. It would define the unchanging self as negentropy resources, which could be regarded as kind of Akashic records. During the

next "re-incarnation" after the first reduction to opposite boundary of CD the NE associated with the reduced state would serve as new Akashic records for the time reversed self. If NMP reduces to the statistical increase of $h_{eff}/h = n$ the consciousness information contents of the Universe increases in statistical sense. In the best possible world of SNMP it would increase steadily.

6.2.2 Does NMP reduce to number theory?

The heretic question that emerged quite recently is whether NMP is actually needed at all! Is NMP a separate principle or could NMP reduced to mere number theory [K16]? Consider first the possibility that NMP is not needed at all as a separate principle.

(a) The value of $h_{eff}/h = n$ should increase in the evolution by the phase transitions increasing the dimension of the extension of rationals. $h_{eff}/h = n$ has been identified as the number of sheets of some kind of covering space. The Galois group of extension acts on number theoretic discretizations of the monadic surface and the orbit defines a covering space. Suppose n is the number of sheets of this covering and thus the dimension of the Galois group for the extension of rationals or factor of it.

(b) It has been already noticed that the "big" state function reductions giving rise to death and reincarnation of self could correspond to a measurement of $n = h_{eff}$ implied by the measurement of the extension of the rationals defining the adeles. The statistical increase of n follows automatically and implies statistical increase of maximal entanglement negentropy. Entanglement negentropy increases in statistical sense.

The resulting world would not be the best possible one unlike for a strong form of NMP demanding that negentropy does increaes in "big" state function reductions. n also decrease temporarily and they seem to be needed. In TGD inspired model of bio-catalysis the phase transition reducing the value of n for the magnetic flux tubes connecting reacting bio-molecules allows them to find each other in the molecular soup. This would be crucial for understanding processes like DNA replication and transcription.

(c) State function reduction corresponding to the measurement of density matrix could occur to an eigenstate/eigenspace of density matrix only if the corresponding eigenvalue and eigenstate/eigenspace is expressible using numbers in the extension of rationals defining the adele considered. In the generic case these numbers belong to N-dimensional extension of the original extension. This can make the entanglement stable with respect to state the measurements of density matrix.

A phase transition to an extension of an extension containing these coefficients would be required to make possible reduction. A step in number theoretic evolution would occur. Also an entanglement of measured state pairs with those of measuring system in containing the extension of extension would make possible the reduction. Negentropy could be reduced but higher-D extension would provide potential for more negentropic entanglement and NMP would hold true in the statistical sense.

(d) If one has higher-D eigen space of density matrix, p-adic negentropy is largest for the entire subspace and the sum of real and p-adic negentropies vanishes for all of them. For negentropy identified as total p-adic negentropy SNMP would select the entire sub-space and NMP would indeed say something explicit about negentropy.

6.2.3 Or is NMP needed as a separate principle?

Hitherto I have postulated NMP as a separate principle [K16]. Strong form of NMP (SNMP) states that Negentropy does not decrease in "big" state function reductions corresponding to death and re-incarnations of self.

One can however argue that SNMP is not realistic. SNMP would force the Universe to be the best possible one, and this does not seem to be the case. Also ethically responsible free will would be very restricted since self would be forced always to do the best deed that is

increase maximally the negentropy serving as information resources of the Universe. Giving up separate NMP altogether would allow to have also "Good" and "Evil".

This forces to consider what I christened weak form of NMP (WNMP). Instead of maximal dimension corresponding to N-dimensional projector self can choose also lower-dimensional sub-spaces and 1-D sub-space corresponds to the vanishing entanglement and negentropy assumed in standard quantum measurement theory. As a matter fact, this can also lead to larger negentropy gain since negentropy depends strongly on what is the large power of p in the dimension of the resulting eigen sub-space of density matrix. This could apply also to the purely number theoretical reduction of NMP.

WNMP suggests how to understand the notions of Good and Evil. Various choices in the state function reduction would correspond to Boolean algebra, which suggests an interpretation in terms of what might be called emotional intelligence [K26]. Also it turns out that one can understand how p-adic length scale hypothesis - actually its generalization - emerges from WNMP [K36].

(a) One can start from ordinary quantum entanglement. It corresponds to a superposition of pairs of states. Second state corresponds to the internal state of the self and second state to a state of external world or biological body of self. In negentropic quantum entanglement each is replaced with a pair of sub-spaces of state spaces of self and external world. The dimension of the sub-space depends on which pair is in question. In state function reduction one of these pairs is selected and deed is done. How to make some of these deeds good and some bad? Recall that WNMP allows only the possibility to generate NNE but does not force it. WNMP would be like God allowing the possibility to do good but not forcing good deeds.

Self can choose any sub-space of the subspace defined by $k \leq N$-dimensional projector and 1-D subspace corresponds to the standard quantum measurement. For $k = 1$ the state function reduction leads to vanishing negentropy, and separation of self and the target of the action. Negentropy does not increase in this action and self is isolated from the target: kind of price for sin.

For the maximal dimension of this sub-space the negentropy gain is maximal. This deed would be good and by the proposed criterion NE corresponds to conscious experience with positive emotional coloring. Interestingly, there are $2^k - 1$ possible choices, which is almost the dimension of Boolean algebra consisting of k independent bits. The excluded option corresponds to 0-dimensional sub-space - empty set in set theoretic realization of Boolean algebra. This could relate directly to fermionic oscillator operators defining basis of Boolean algebra - here Fock vacuum would be the excluded state. The deed in this sense would be a choice of how loving the attention towards system of external world is.

(b) A map of different choices of k-dimensional sub-spaces to k-fermion states is suggestive. The realization of logic in terms of emotions of different degrees of positivity would be mapped to many-fermion states - perhaps zero energy states with vanishing total fermion number. State function reductions to k-dimensional spaces would be mapped to k-fermion states: quantum jumps to quantum states!

The problem brings in mind quantum classical correspondence in quantum measurement theory. The direction of the pointer of the measurement apparatus (in very metaphorical sense) corresponds to the outcome of state function reduction, which is now 1-D subspace. For ordinary measurement the pointer has k positions. Now it must have $2^k - 1$ positions. To the discrete space of k pointer positions one must assign fermionic Clifford algebra of second quantized fermionic oscillator operators. The hierarchy of Planck constants and dark matter suggests the realization. Replace the pointer with its space-time k-sheeted covering and consider zero energy energy states made of pairs of k-fermion states at the sheets of the n-sheeted covering? Dark matter would be therefore necessary for cognition. The role of fermions would be to "mark" the k space-time sheets in the covering.

The cautious conclusion is that NMP as a separate principle is not necessary and follows

in statistical sense from the unavoidable increase of $n = h_{eff}/h$ identified as dimension of extension of rationals define the adeles if this extension or at least the dimension of its Galois group is observable.

6.3 p-Adic physics as correlate of cognition and imagination

The items in the following list give motivations for the proposal that p-adic physics could serve as a correlate for cognition and imagination.

(a) By the total disconnectedness of the p-adic topology, p-adic world decomposes naturally into blobs, objects. This happens also in sensory perception. The pinary digits of p-adic number can be assigned to a p-tree. Parisi proposed in the model of spin glass [B6] that p-adic numbers could relate to the mathematical description of cognition and also Khrennikov [J1] has developed this idea. In TGD framework that idea is taken to space-time level: p-adic space-time sheets represent thought bubbles and they correlate with the real ones since they form cognitive reprentations of the real world. SH allows a concrete realization of this.

(b) p-Adic non-determinism due to p-adic pseudo constants suggests interpretation in terms of imagination. Given 2-surfaces could allow completion to p-adic preferred extremal but not to a real one so that pure "non-realizable" imagination is in question.

(c) Number theoretic negentropy has interpretation as negentropy characterizing information content of entanglement. The superposition of state pairs could be interpreted as a quantum representation for a rule or abstracted association containing its instances as state pairs. Number theoretical negentropy characterizes the relationship of two systems and should not be confused with thermodynamical entropy, which characterizes the uncertainty about the state of single system.

The original vision was that p-adic non-determinism could serve as a correlate for cognition, imagination, and intention. The recent view is much more cautious. Imagination need not completely reduce to p-adic non-determinism since it has also real physics correlates - maybe as partial realizations of SH as in nerve pulse pattern, which does not propagate down to muscles.

A possible interpretation for the solutions of the p-adic field equations would be as geometric correlates of cognition, imagination, and perhaps even intentionality. Plans, intentions, expectations, dreams, and possibly also cognition as imagination in general could have p-adic cognitive space-time sheets as their geometric correlates. A deep principle seems to be involved: incompleteness is the characteristic feature of p-adic physics but the flexibility made possible by this incompleteness is absolutely essential for imagination and cognitive consciousness in general.

The most feasible view is that the intersections of p-adic and real space-time surfaces define cognitive representations of real space-time surfaces (PEs, [K2, K37, K39]). One could also say that real space-time surface represents sensory aspects of conscious experience and p-adic space-time surfaces its cognitive aspects. Both real and p-adics rather than real or p-adics.

The identification of p-adic pseudo constants as correlates of imagination at space-time level is indeed a further natural idea.

(a) The construction of PEs by SH from the data at 2-surfaces is like boundary value problem with number theoretic discretization of space-time surface as additional data. PE property in real context implies strong correlations between string world sheets and partonic 2-surfaces by boundary conditions a them. One cannot choose these 2-surfaces completely independently in real context.

(b) In p-adic sectors the integration constants are replaced with pseudo-constants depending on finite number of pinary digits of variables depending on coordinates normal to string world sheets and partonic 2-surfaces. The fixing of the discretization of space-time surface would allow to fix the p-adic pseudo-constants. Once the number theoretic

discretization of space-time surface is fixed, the p-adic pseudo-constants can be fixed. Pseudo-constant could allow a large number of p-adic configurations involving string world sheets, partonic 2-surfaces, and number theoretic discretization but not allowed in real context.

Could these p-adic PEs correspond to imaginations, which in general are not realizable? Could the realizable intentional actions belong to the intersection of real and p-adic WCWs? Could one identify non-realistic imaginations as the modes of WCW spinor fields for which 2-surfaces are not extendable to real space-time surfaces and are localized to 2-surfaces? Could they allow only a partial continuation to real space-time surface. Could nerve pulse pattern representing imagined motor action and not proceeding to the level of muscles correspond to a partially real PE?

Could imagination and problem solving be search for those collections of string world sheets and partonic 2-surfaces, which allow extension to (realization as) real PEs? If so, p-adic physics would be there as an independent aspect of existence and this is just the original idea. Imagination could be realized in state function reduction, which always selects only those 2-surfaces, which allow continuation to real space-time surfaces. The distinction between only imaginable and also realizable would be the extendability by using strong form of holography.

(c) An interesting question is why elementary particles are characterized by preferred p-adic primes (primes near powers of 2, in particular Mersenne primes). Could the number of realizable imaginations for these primes be especially large?

I have the feeling that this view allows respectable mathematical realization of imagination in terms of adelic quantum physics. It is remarkable that SH derivable from - you can guess, SGCI (the Big E again!), plays an absolutely central role in it.

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